SIGNAL-IN-SPACE MINIMUM AVIATION SYSTEM PERFORMANCE STANDARDS (MASPS) FOR ADVANCED VHF DIGITAL DATA COMMUNICATIONS INCLUDING COMPATIBILITY WITH DIGITAL VOICE TECHNIQUES

RTCA/DO-224A
September 13, 2000

Prepared by: SC-172

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Foreword

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Executive Summary

The purpose of this document is to define Minimum Aviation System Performance Standards (MASPS) for the signal-in-space characteristics for an advanced Very High Frequency (VHF) digital data communications radio, including compatibility with digital voice techniques. The MASPS is divided into three sections; an introduction, aviation user requirements, and technical characteristics.

The introductory section provides VHF communications system characteristics including aeronautical VHF communications frequencies utilized and spectrum congestion. Service rules as defined by the Federal Communications Commission (FCC) and the Federal Aviation Administration (FAA) are also provided. Principles of operation of the current VHF voice and data systems and the proposed future system are presented. General applications are divided into three categories; they are Air Traffic Services, Aeronautical Operational Control, and Aeronautical Administrative Communications. Current system interconnection, routing, integration considerations and deficiencies are highlighted.

The aviation user requirements section identifies the users of the systems and specific aircraft characteristics. The expected availability and integrity of the avionics are described. System interoperability and compatibility requirements are emphasized to assure coexistence with the present analog voice system.

The technical characteristics section describes the new system. Two modes of operation are defined: VDL Mode 2 and VDL Mode 3. VDL Mode 2 refers to the operation of the Carrier Sense Multiple Access (CSMA) scheme, to support data link compatibility. VDL Mode 3 refers to the functionally simultaneous voice and data link capability of the Time Division Multiple Access (TDMA) architecture.

The signal-in-space may be used for either or both modes of operation provided implementation is in accordance with the VDL Mode 2 and VDL Mode 3 characteristics described herein and with industry standards. The definition, description, and specification of both modes are expected to continue to evolve as the industry, the service providers, and the users further develop future system concepts and capabilities.

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1.0 INTRODUCTION

The purpose of this document is to provide RTCA Minimum Aviation System Performance Standards (MASPS) that define the signal-in-space characteristics for an advanced Very High Frequency (VHF) digital data communications radio, including compatibility with digital voice techniques. This document examines the VHF communications system characteristics and principles of operation for both VHF voice and data system elements. Aviation user requirements and system requirements are considered and technical characteristics are developed for airborne transceivers and ground transmitters/receivers. Finally, considerations are examined with regard to accommodating existing systems while making a transition to a new improved VHF data link.

All of these documents in the list above fall under the proprietary disclaimer note.

1.1 VHF Communications System Characteristics

1.1.1 Introduction

The characteristics of the present air/ground VHF communications system are contained in the Federal Communications Commission (FCC) Rules (47 CFR Part 87), the International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) (Annex 10, Volume I, Chapter 4 Paras. 4.5 - 4.7), and RTCA/DO-186 (Minimum Operational Performance Standards (MOPS) For Airborne Radio Communications Equipment Operating Within the Radio Frequency Range 117.975 – 136.000 MHz. These documents set forth the minimum mandatory and desired operational performance standards for VHF air/ground communications systems. The following list summarizes pertinent industry standards and their specific versions.

Reference Document Name	Versions
ARINC Specification –Air-Ground Character-Oriented Protocol Specification	618-5
ARINC Specification – ACARS Protocols for Avionic End Systems	619-1
ARINC Specification – Data Link Ground System Standard and Interface Specification (DGSS/IS)	620-4
ARINC Specification – ATS Data Link Applications Over ACARS Air-Ground Network	622-3
ARINC Sspecification – Character-Oriented Air Traffic Services (ATS) Applications	623-2
ARINC Specification - VHF Digital Link Implementation Provisions	631-3
ARINC Specification – Aeronautical Telecommunications Network (ATN) Implementation Provisions, Part 1, Protocols and Services	637P1-1
ARINC Characteristic – Aircraft Communications Addressing and Reporting System (ACARS)	597-5
ARINC Characteristic – Enhanced ACARS Avionics	597A

ARINC Characteristic – Airborne VHF Communications Transceiver	716-10
ARINC Characteristic – Aircraft Communications Address and Reporting System (ACARS)	724-9
ARINC Characteristic – Aircraft Communications Address and Reporting System (ACARS)	724B-3
ARINC Characteristic – VHF Data Radio	750-3
ARINC Characteristic – Communications Management Unit (CMU) Mark 2	758-1
ICAO Document - Manual of Technical Provisions for the Aeronautical Telecommunication Network	9705
ICAO Document - Comprehensive Aeronautical Telecommunication Network Manual	9739
ICAO Document - Manual on VDL Mode 2 Technical Specifications	Expect Nov '01
ICAO Document - Manual on VDL Mode 3 Technical Specifications	Expect Nov '01
ICAO Document - Implementation Manual for VDL Mode 2	Expect Nov '01
ICAO Document - Implementation Manual for VDL Mode 3	Expect Nov '01
ISO Standard - Information Technology -- Telecommunications and information exchange between systems -- High-level data link control (HDLC) procedures -- Frame Structure	3309
ISO Standard - Information Technology -- Telecommunications and information exchange between systems -- High-level data link control (HDLC) procedures -- Elements of procedures	4335
ISO Standard - Information Technology -- Telecommunications and information exchange between systems -- High-level data link control (HDLC) procedures -- Classes of procedures	7809
ISO Standard - Information Technology -- Data Communications -- X.25 Packet Layer Protocol for Data Terminating Equipment	8208
ISO Standard - Information Technology -- Protocol for providing the connectionless-mode network service	8473
ISO Standard - Information Technology -- Telecommunications and information exchange between systems -- High-level data link control (HDLC) procedures -- General purpose XID frame information field content and format	8885
ISO Standard - OSI Data Link Service Definition	8886.3
ISO Standard - Information Technology -- Telecommunications and information exchange between systems -- End system to intermediate system routeing exchange protocol for use in conjunction with the Protocol for providing the connectionless-mode network service (ISO 8473)	9542
ISO Standard - Local Area Networks -- MAC Service Definition	DP 10039
ISO Standard - Information Technology -- Telecommunications and information exchange between systems -- Protocol for exchange of Inter-Domain Routeing Information among intermediate systems to support forwarding of ISO 8473 PDUs	10747
ITU-T Standard - International Numbering Plan for Public Data Networks	X.121
RTCA Environmental Conditions and Test Procedures for Airborne Equipment	DO-160D

RTCA Minimum Operational Performance Standards for Airborne Radio Communications Equipment Operating Within the Radio Frequency Range 117.975 – 137.000 MHz	DO-186a
RTCA VHF Air-Ground Communications System Improvements Alternatives Study and Selection of Proposals for Future Action	DO-225

1.1.2 Definitions of Terms

Please note that these terms and definitions are to be used for the purposes of this MASPS.

Administration Field: A field within the Aeronautical Telecommunications Network (ATN) Network Service Access Point (NSAP) address which is used to sub-divide the Network Addressing Domain that is identified in the Version field of the address. The partition of the Network Addressing Domain permits domain management by separate administrations or organizations.

Administrative Region Selector (ARS): A field within the ATN NSAP address which identifies a Network Addressing Domain that will correspond to each identified Routing Domain.

Aeronautical Mobile Service: A mobile service between aeronautical stations and aircraft stations, or between aircraft stations, in which survival craft stations may participate; emergency locator transmitter (ELT) stations may also participate in this service on designated distress and emergency frequencies.

Aeronautical Mobile (Route) Service (AM(R)S): An aeronautical mobile service reserved for communications relating to safety and regularity of flight, primarily along national or international air routes.

Aeronautical Station: A land station in the aeronautical mobile service.

Aeronautical Telecommunications Network (ATN): An internetwork architecture that allows ground, air-ground, and aircraft data subnetworks to interoperate by adopting common interface services and protocols based on the International Organization for Standardization (ISO) Open Systems Interconnection (OSI) Reference Model.

Aircraft Station: A mobile station in the aeronautical mobile service, other than a survival craft station, located on board an aircraft.

Air-Ground Communication: Two-way communications between aircraft and stations on the surface of the earth.

Aircraft Address: A unique combination of 24 bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.

Assigned Frequency: The center of the frequency band assigned to a station.

Assigned Frequency Band: The frequency band within which the emission of a station is authorized; the width of the band equals the necessary bandwidth plus twice the absolute value of the frequency tolerance.

Asynchronous Balanced Mode (ABM): A balanced operational mode in which a data link connection has been established between two service access points. Either data link entity can send commands at any time and initiate responses without receiving permission from the peer data link entity on the connection.

Asynchronous Disconnected Mode (ADM): A balanced non-operational mode in which no logical data link connection exists between two link layer entities. A connection must be established before data can be sent.

ATN Router: An intermediate system used to interconnect subnetworks conforming to ICAO Document 9705 Manual on ATN Technical Provisions.

Autotune Function: The function, performed by the link management entity, allows a ground station to command an aircraft to change frequencies.

Bit Error Rate (BER): BER is expressed as the ratio of the number of erroneous bits received to the total number of bits received. As used in this document, the term BER always refers to the uncorrected BER, that is, the BER experienced on the channel without the benefit of Forward Error Correction (FEC).

Broadcast: A transmission intended to be received by all stations.

Broadcast Handoff: The process by which a ground Link Management Entity (LME) commands certain aircraft to execute a link handoff and optionally maintain its current subnetwork connections, without the need to explicitly confirm the link handoff or optionally the subnetwork connection maintenance.

Broadcast Link Handoff: The process by which the ground LME commands certain aircraft to execute a link handoff to a specific ground station without the need to explicitly confirm the link handoff.

Broadcast Subnetwork Connection Handoff: The process by which a ground LME commands certain aircraft to execute a link handoff to a specific ground station and maintain its current subnetwork connections

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without the need to explicitly confirm the link handoff or the subnetwork connections maintenance.

Burst: A time-defined, contiguous set of one or more related signal units which may convey user information and protocols, signaling and any necessary preamble.
Coast Timing: A timing state where the aircraft radio is not receiving timing synchronization pulses from the ground station. The aircraft user will attempt to synchronize with any non-coasting aircraft users instead.

Code Rate: The ratio of information bits to overall transmitted bits for an error correction code.

Class of Emission: The set of characteristics of an emission, designated by standard symbols, e.g., type of modulation of the main carrier, modulating signal, type of information to be transmitted, and also, if appropriate, any additional signal characteristics. (47 CFR Section 2.201)

Current Link (or current ground station): Either the ground-to-aircraft link or the active link when in the process of a handoff.

Data Circuit-terminating Equipment (DCE): A DCE is a network provider equipment used to facilitate communications between Data Terminal Equipment (DTE).

Data Link Entity (DLE): A protocol state machine capable of setting up and managing a single data link connection.

Data Link Service Sub-layer (DLS): The sub-layer that resides above the MAC sub-layer. The DLS manages the transmit queue, creates and destroys DLEs for connection-oriented communications, provides facilities for the LME to manage the DLS, and provides facilities for connectionless communications.

Data Terminal Equipment (DTE): A DTE is an endpoint of a subnetwork connection. Immediately above the DTE is the ATN.

Effective Data Rate: The actual instantaneous data throughput realized after overheads imposed by bit stuffing and by any forward error correction encoding, but not retransmissions.

Emission: Radiation produced, or the production of radiation, by a radio transmitting station.

Expedited Subnetwork Connection Establishment: The process by which an aircraft DTE establishes a subnetwork connection with a ground DTE with which it does not have a subnetwork connection during link establishment (or aircraft-initiated handoff).

Expedited Subnetwork Connection Maintenance: The process by which an aircraft DTE maintains a subnetwork connection with a ground DTE with which it has a subnetwork connection during the link handoff.

Explicit Subnetwork Connection Establishment: The process by which an aircraft DTE establishes a subnetwork connection with a ground DTE with which it does not have a subnetwork connection only after completing the link establishment (or handoff).

Explicit Subnetwork Connection Maintenance: The process by which an aircraft DTE maintains a subnetwork connection with a ground DTE with which it has a subnetwork connection only after completing the link handoff.

Extended Golay code: A rate 1/2 error correction code capable of correcting any error pattern of three or less bit errors and detecting four bit error patterns within a 24 bit block size.

Former_GNI$_P$: During handoff between GNI groups, the previous GNI$_P$ to which the aircraft was connected.

Frame: The link layer frame is composed of a sequence of address, control, information and FCS fields, bracketed by opening and closing flag sequences.

Frequency Stability: The maximum permissible departure by the center frequency of the frequency band occupied by an emission from the assigned frequency, or by the characteristic frequency of an emission from the reference frequency. The frequency stability is expressed in parts per million or in Hertz.

Ground Network Interface: The ground equipment that interfaces with the voice switch, ATN router, and the remote radio via the VDL protocols.

Harmful Interference: Interference which endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radio communication service operating in accordance with the International Telecommunication Union (ITU) Radio Regulations.

Initiated Handoff: The transmission process by which a station initiates link handoff.

Integrity: The measure of induced errors in messages transferred by a system. An error is considered to include extraneous, modified, or missing information; failure of delivery to the intended recipient; and misdelivery. Integrity is expressed in terms of residual error probability -

- packet error probability in the case of packet-mode communications, bit error probability in the case of circuit-mode communications. (See also Residual Error Probability)

Interference: The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radio communication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.

Internetworking Protocol: A protocol that transfers data packets between intermediate systems (IS) and end systems (ES) interconnected by subnetworks and that is supported by the routing protocols and addressing plan.

Link: A link connects an aircraft DLE and a ground DLE and is uniquely specified by the combination of aircraft DLS address and the ground DLS address.

Link Establishment: The process by which an aircraft and a ground LME discover each other, determine to communicate with each other, decide upon the communications parameters, create a link and initialize its state before beginning communications.

Link Handoff: The process by which peer LMEs, already in communication with each other, create a link between an aircraft and a new ground station before disconnecting the old link between the aircraft and the current ground station.

Link Layer: The layer that lies immediately above the physical layer in the Open Systems Interconnection protocol model. The link layer provides for the reliable transfer of information across the physical media. It is subdivided into the data link sub-layer and the media access control sub-layer.

Link Management Entity (LME): A protocol state machine capable of acquiring, establishing, and maintaining a connection to a single peer system. An LME establishes data link connections, "hands-off" those connections, and manages the media access control sub-layer and physical layer. An aircraft LME tracks how well it can communicate with the ground stations of a single ground system.

Local User ID: A unique identification of a specific aircraft that is used by the participants in a VDL subnetwork. The Local User ID consists of a 2-bit User Group ID prefix followed by a 6-bit numerical suffix.

MAC Cycle: The standard timing cycle that consists of two consecutive (even and odd) TDMA frames.

M Burst: A management channel data block of symbols. This burst contains signaling information needed for media access and link status monitoring. The uplink M burst is used for timing and network

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management. The downlink M burst is used for management functions and may also include additional optional voice features: i.e., call waiting and message waiting indications.

Mean Power (of a radio transmitter): The average power supplied to the antenna transmission line by a transmitter during an interval of time sufficiently long compared with the lowest frequency encountered in the modulation taken under normal operating conditions.

Media Access Control (MAC): The sub-layer that acquires the data path and controls the movement of bits over the data path.

Multicast: A transmission intended to be received by multiple stations.

Necessary Bandwidth: For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specific conditions.

Network Layer: The layer that provides the upper layers with independence from the data transmission and routing functions used to connect systems. The network layer is responsible for routing and relaying functions both within any subnetwork and throughout the aeronautical internetworking domain.

New Link (or new ground station): After successful completion of handoff (or link establishment), the new "current" link or ground station.

N(r): The receive sequence number at the link layer, which indicates the sequence number of the next expected frame (and explicitly acknowledges all lesser numbered frames).

N(s): The send sequence number at the link layer, which indicates the sequence number associated with a transmitted frame.

Occupied Bandwidth: The width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage B/2 of the total mean power of a given emission. Unless otherwise specified by the ITU-R (Formerly CCIR) for the appropriate class of emission, the value of B/2 should be taken as 0.5% (ITU).

Old Link (or old ground station): Following link establishment during a handoff, the link that was previously the "current" link becomes the "old" link.

Operative_GNI$_P$: The current Primary GNI servicing data communications for an aircraft.

Out-of-Band Emission: Emission of a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions.

Physical Layer: The lowest level layer in the Open Systems Interconnection protocol model. The physical layer is concerned with the transmission of binary information over the physical medium (e.g., VHF).

Polling: A procedure by which the ground station interrogates aircraft stations, one at a time, to determine status/control functions.

Primary GNI (GNI$_P$): The Ground Network Interface (GNI) within a GNI group that physically attaches to an ATN router and provides connectivity to the router for the rest of the GNI group, which are referred to as Secondary GNIs.

Private Parameters: The parameters that are contained in exchange identity (XID) frames and that are unique to the VHF digital link environment.

Proposed Link (or proposed ground station): The link being negotiated (in a handoff) to replace the current link.

Quality of Service: The information relating to data transfer characteristics used by various communication protocols to achieve various levels of performance for network users.

Real-Time: When the delay in receiving transmitted digital information (latency) is tolerable compared to a human being's expectation of "instantaneous" transmission.

Reed-Solomon Codes: Error correction codes capable of correcting symbol errors.

Requested Handoff: The one-transmission process by which a station requests its peer entity to initiate a link handoff.

Residual Packet Error Probability: (Applicable to packet-mode data communications.) Defined by International Organization for Standardardization (ISO) as the likelihood that a particular packet will be lost, duplicated or delivered incorrectly. An incorrectly delivered packet is one in which the user data are delivered in a corrupted condition (see Undetected Packet Error Probability), or the user data are delivered to an incorrect receiving user. The probability is estimated as the ratio of lost, duplicated, or incorrectly delivered packets to total packets transmitted by the system (or subsystem) during a measurement period. Packets lost due to error by the user are not included.

Safety Service: Any radio communication service used permanently or temporarily for the safeguarding of human life and property.

Service Primitives: The status and control information that must be available to the receiving entity to properly process incoming information. A service primitive may contain parameters. If parameters exist, they describe information that is defined either as mandatory (M) or optional (O) for conformance to a particular communications standard.

Service Provider: An entity at a layer that provides services to the layer above. These services are provided at service access points through the use of service primitives.

Service User: An entity at a layer that makes use of the services that are provided at service access points by the layer below through the use of service primitives.

Simplex: Transmission or reception on a single frequency but not simultaneously.

Slotted Aloha: A media access control technique for multiple access transmission. A station can only transmit at the beginning of a time slot.

Spurious Emissions: Emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

Squelch Window: The time period a radio searches for the beginning of a message.

Station: A VDL-capable entity. A station may either be an aircraft station or a ground station. A station is a physical entity that transmits and receives frames over the air-ground interface and comprises, at a minimum: a physical layer, media access control sub-layer, and a unique DLS address.

Stuck Microphone: Transmitter operation when such operation is not intended.

Subnetwork Connection: A long-term association between an aircraft DTE and a ground DTE using successive virtual calls to maintain context across link handoffs.

Subnetwork Connection Maintenance: The process by which the VDL SNDCF maintains subnetwork context from one subnetwork connection to the next during handoffs.

Subnetwork Connection Management: The process by which the VDL SNDCF initially establishes a connection and then maintains it during handoffs.

Subnetwork Dependent Convergence Function (SNDCF): A function that matches the characteristics and services of a particular subnetwork to those characteristics and services required by the internetworking process.

Subnetwork Entity: A subnetwork entity is a packet layer entity as defined in ISO 8208. In this document, the phrase "ground DCE" will be used for the subnetwork entity in a ground station communication with an aircraft; the phrase "ground DTE" will be used for the subnetwork entity in a ground router communication with an aircraft station; and, the phrase "aircraft DTE" will be used for the subnetwork entity in an aircraft communicating with the station.

Subnetwork System Management Entity (SN_SME): The main role of the SN_SME is to generate events which advertise a change in the subnetwork connectivity.

Subnetwork Layer: The layer that establishes, manages, and terminates connections across a subnetwork.

Switching Time: In VDL Mode 3, the switching time is the time for a radio to switch from reception to transmission (R/T), or from transmission to reception (T/R). This time should be measured from the center of the last transmitted symbol to the center of the first symbol of the unique word of the received signal.

Symbol: Element of modulation where a number of data bit patterns are mapped to defined phase changes for on-air transmission.

System: A VDL-capable system comprises one or more stations and the associated VDL management entity. A system may either be an aircraft or a ground system.

System Configuration: Each system configuration defines the allocation of TDMA time slot resources to various user groups supported by one or more ground stations sharing the same 25 kHz VHF channel frequency.

T: The symbol period.

TDMA Frame: The basic unit of time (120 ms) which consists of 3 or 4 time slots. In any voice communication, a radio will transmit digitized voice bits periodically once per frame.

Time Slot: A TDMA timing unit allocated for an M burst and V/D burst.

Truncation: A timing state where the aircraft timing uncertainty is such that the V/D (voice) burst duration is reduced to increase the guard time.

The additional guard time provides more room for timing error without interfering with adjacent time slots.

Undetected Packet Error Probability: The likelihood that a packet delivered by the system (or subsystem) contains one or more erroneous data bits as compared with the data presented to the system. This is one component of Residual Packet Error Rate (see Residual Packet Error Probability). In practice, higher protocol layers, external to the system, can be employed to reduce significantly the probability of data error.

Unicast: A transmission addressed to a single station.

Unwanted Emissions: Consist of spurious emissions and out-of-band emissions.

User Group: A group of ground and/or aircraft stations which share voice and/or data connectivity. For voice communications all members of a user group can access all communications. For data, communications include point-to-point connectivity for air-to-ground messages, and point-to-point and broadcast connectivity for ground-to-air messages.

User Group ID: User Group ID, which is synonymous with Group ID, is a 2 bit code (at most A to D) that together with the channel frequency uniquely identifies the VDL Mode 3 circuit.

V/D Burst: A burst that is used for the transmission of a user's voice or data. V/D (voice) is used for voice transmission and V/D (data) is used for data transmission.

VDL Management Entity (VME): A VDL-specific function that provides, inter alia., the quality of service requested by the ATN-defined SN_SME. A VME uses the LMEs (that it creates and destroys) to negotiate the quality of service available from peer systems.

VDL Mode 2: A constituent mobile subnetwork of the Aeronautical Telecommunication Network (ATN), operating in the aeronautical mobile VHF frequency band. VDL Mode 2 uses the Differential Eight Phase Shift Keyed (D8PSK) modulation scheme providing a 31.5 kbs data rate and uses a Carrier Sense Multiple Access (CSMA) scheme. VDL Mode 2 allows for alternative transmission paths for individual segment(s) (“packet(s)”) of a given message or series of messages for high-throughput service.

VDL Mode 3: A constituent mobile subnetwork of the ATN (operating in the aeronautical mobile VHF frequency band). VDL Mode 3 uses the D8PSK modulation scheme and the TDMA media access control scheme. VDL Mode 3 allows for functionally simultaneous voice and data link.

VHF Digital Link (VDL): Radio standards being defined by ICAO.

VDL Specific DTE Addressing (VSDA): The VDL MASPS supports two addressing options at the subnetwork layer. The default addressing is called VDL Specific DTE Addressing and should be supported by all VDL entities. Optionally, VDL MASPSs supports X.121 addressing. The VSDA consists of six octets. The first three octets of VSDA should be the same as the ATN Administration Domain Identifier (ADM) field as defined in the ATN SARPs. The service provider assigns the second three octets of VSDA. The service provider may use these three octets to uniquely address an air/ground router or may use them as a routing area identifier (same as the ATN ARS field specified in the ATN SARPs). If the VSDA assigned by the DSP does not uniquely identify a specific air /ground router, then the ground system should support X.121 addressing option.

Vocoder: A low bit rate voice encoder/decoder.

Vocoder Frame: A window of time in which the analog speech waveform is used by the vocoder to process and generate the encoded digital voice output or to perform the reverse process to regenerate from a digital voice data block the corresponding analog speech waveform.

Voice Analysis: The process where speech is modeled and converted into parameters.

Voice Synthesis: The process where voice analysis parameters are used to generate speech.

Voice Unit: A device that provides a half duplex audio and signalling interface between the user and VDL.

1.1.3 Aeronautical VHF Communications Frequencies

The VHF band 117.975 - 137 MHz is allocated to Aeronautical Mobile (Route) Service (AM(R)S) on an exclusive basis. The lowest assignable frequency is 118 MHz and the highest is 136.975 MHz.

> Note: *In the future, the allocation for AM(R)S may be extended down to 108 MHz.*

1.1.4 Spectrum Congestion

It has long been recognized that the civil aviation requirements for air-ground voice communications in the 117.975 -137 MHz VHF band vary widely from region to region, just as the frequency and number of flights vary. It is becoming apparent that there is a shortage of assignable aeronautical VHF communications channels in some parts of the world. Shortages of communications channels could seriously affect the implementation of Air Traffic Services (ATS) and Aeronautical Operational Control (AOC) enhancements needed to cope with current and projected air traffic communication needs. Studies are being conducted by ICAO and other agencies to improve the utilization of the 117.975 - 137 MHz VHF band to satisfy current and projected communications requirements.

1.1.5 Service Rules

The Service Rules for the use of 117.975 - 137 MHz Aeronautical Mobile (R) Service are contained in the Federal Communications Commission's Rules Part 87 -- Aviation Services (47 CFR Part 87). General Operating and Flight rules are contained in the Federal Aviation Regulations (14 CFR). Rules pertaining to aeronautical VHF communications are established by the Federal Communications Commission (FCC) and the Federal Aviation Administration (FAA).

1.1.5.1 Federal Communications Commission (FCC)

FCC Rules Part 87 Subpart C (Sections 87.69 - 87.111) -- Operating Requirements and Procedures for the Aviation Radio Services addresses, among other things, maintenance tests, frequency measurements, and transmitter adjustments and test. Subpart D (Sections 87.131 - 87.187) -- Technical Requirements addresses power and emissions, frequency stability, bandwidth of emission, types of emission, emission limitations, modulation requirements, transmitter control requirements, acceptability of transmitters for licensing, and type acceptance of equipment.

1.1.5.2 Federal Aviation Administration (FAA)

Avionics units operating in the VHF AM(R)S air-ground communications frequency band must meet the following Technical Standard Orders (TSOs) or satisfy the essential technical requirements of these TSOs as required during the installation certification process: (1) TSO-C37c, VHF Radio Communication Transmitting Equipment Operating Within the Radio Frequency Range 117.975 - 136.000 MHz, and (2) TSO-C38c, VHF Radio Communication Receiving Equipment Operating Within the Radio Frequency Range 117.975 - 136.000 MHz. These TSO requirements are based in large part on RTCA/DO-156 and RTCA/DO-157, *MOPS for Airborne Radio Communications Equipment Operating within the Frequency Range 117.975 - 136.000 MHz*. Updates to TSO-C37c and TSO-C38c (TSO C37d and TSO C38d) are based on RTCA/DO-186a, *MOPS for Airborne Radio Communications Equipment Operating Within the Frequency Range 117.975 - 137.000 MHz*. FAA VHF air-ground transmitters must satisfy the following requirement: any spurious frequency emission shall be at least 80 dB below the carrier level of the subject transmission. Ground transmitter power can range from below 10 Watts to 50 Watts; the higher level is normally used only for service radii that are over 60 nautical miles, or in particularly difficult terrain.

1.2 VHF Voice and Data System Elements and Principles of Operation

The future digital VHF system supports bit-oriented air-ground data communications services based on OSI architecture. During the past several years various standards organizations within the aviation community have been participating in, or supporting the development of a new architecture for use in the aeronautical data communications environment.

With this architecture, the Aeronautical Telecommunications Network (ATN) supports interoperability between the various terrestrial, air-ground, and avionics subnetworks through conformance with a single bit-oriented ATN Internetworking Protocol, ATN Addressing Plan, and ATN Routing Plan. The Civil Aviation industry has endorsed the ATN architecture and has incorporated ATN-conforming guidelines in the standards being developed for the three new air-ground subnetworks, or data links known as: Mode S, VDL, and Aviation Satellite Communication System (SATCOM). The ATN architecture provides a single network service interface for the applications and may transmit application information over the Mode S air-ground subnetwork, VHF air-ground subnetwork, or satellite air-ground subnetwork transparently. Additional capabilities and functions include:

a. Use of data compression techniques
b. Support of global internetwork addressing and routing
c. Security and priorities as permitted by OSI conformance
d. Dynamic optimization of VHF media specific parameters will be permitted through avionic/ground system negotiation
e. Support of flight following capability

1.2.1 Principles of Operation for VHF Packet Data System Elements

VDL Mode 2 protocols are used to exchange bit-oriented data across an air-ground VHF data link in an OSI environment. This environment may consist of an accumulation of data processing networks, either public or private, which can be accessed by any user connected to the ATN and employing a compatible application process. All networks and intermediate nodes in the environment must be compatible with the OSI environment. Accommodation of the VDL Mode 2 protocol by the ground network will permit bit-oriented data transfer between the aircraft and the user host via the service provider’s ground network. Non-adaptive, p-persistent CSMA has been chosen for VDL Mode 2. Selection of the best ground station for communication with the aircraft will be negotiated by the ground network and the aircraft. Transmission of periodic uplink Ground Station Information Frames (GSIF),

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sometimes referred to as squitters, when no other traffic is being transmitted, will assist the aircraft in identifying valid frequencies and ground stations.

1.2.2 New VHF Integrated Voice and Data System Elements

The principal elements of the new VHF Integrated Voice and Data System are: 1) preservation of essential capabilities of the current VHF analog voice system, such as "real-time" operation, the "party line", and air-to-air communications for certain applications; 2) solutions to present deficiencies, such as susceptibility to many forms of RF interference, lack of security, "step-on", the "stuck mic" problem, and occasional occurrences of unacceptable voice message integrity/quality; and 3) desirable future system features such as emergency access, call waiting, integrated data communications, computer-assisted controller handoff, and automated frequency changes. A fundamental time division multiple access (TDMA) scheme has been selected as the one best suited to support the above voice system elements. Other multiple accessing schemes such as frequency division multiple access (FDMA) and code division multiple access (CDMA) were also considered, but were rejected for reasons of higher system complexity and/or greater uncertainly in performance.

1.2.3 Principles of Operation for New VHF Integrated Voice and Data System Elements

The new integrated voice and data link system has been designed to satisfy the future system requirements and desirable features identified in the RTCA SC-172 WG-1 report, published as DO-225. This fully digital system will provide functionally simultaneous access to voice and data link through the implementation of the TDMA system architecture. This architecture utilizes three or four time slots per 120 ms frame, each of which may be independently assigned to transmit voice or data. A full description of the TDMA architecture is found in Section 3.3.1.3. The voice portion of this architecture is meant to continually support real time ~~(250 ms end-to-end delay)~~ capability. The vocoder will operate at a channel nominal data rate of no more than 4800 bps including any error correction overhead inherent in the performance of the devices.

1.3 General Applications

1.3.1 Introduction

The system will be used for air-ground communications that can be categorized into three main types:

- Air Traffic Services (ATS)
- Aeronautical Operational Control (AOC)

- Aeronautical Administrative Communications (AAC)

The first two are services for the safety and regularity of flight and must be accorded appropriate priority, as specified by FCC Part 87.265, whereas AAC messages are associated with the commercial management communications. Aeronautical Public Correspondence (APC) and Entertainment Services are prohibited in the VHF system.

1.3.2 Data Services

Rapidly increasing usage of air-ground data link is expected for all categories of communications. For ATS applications, data communications will be essential for the implementation of new communications/navigation/surveillance services and support of new Air Traffic Management (ATM) procedures.

1.3.2.1 Air Traffic Services

Air Traffic Services (ATS) encompasses a broad variety of safety communications required to support civil aviation system safety. These communications include Air Traffic Control (ATC) and Flight Information Services (FIS). Digital communications including digital voice offer the potential to improve the capacity and capability of the communications system supporting ATS, thereby improving air traffic management efficiency and safety. Data Link is expected to relieve congestion on existing voice radio channels while increasing the overall safety and productivity of the ATC system. Digital information transfer provides the ability to discretely address individual aircraft and to link the automated processes on the aircraft, particularly the flight management computer functions, with those on the ground. In addition to providing a means of exchange of digital tactical ATC messages, it is envisaged that an air-ground data link will be used for airborne access to ground data bases and the relay of air-derived data. The following potential ATS data link message applications have been identified:

- tactical control messages (2D, 3D and 4D vectors)
- aircraft intent information
- automatic dependent surveillance
- flight plan filing
- issue of clearances (e.g., pre-departure, oceanic entry)
- hand-off messages
- traffic situation
- weather broadcasts (e.g., Automated Weather Observing System [AWOS], Automated Surface Observing System [ASOS])
- access to weather databases
- reporting of air-derived weather data
- Automated Terminal Information System (ATIS)
- hazardous weather alerts (e.g., Significant Meteorological Information [SIGMETS], wind shear)

1.3.2.2 Aeronautical Operational Control (AOC)

ICAO defines AOC as communications required for the exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of safety of the aircraft and the regularity and efficiency of a flight. AOC communications are characterized by messages exchanged between an aircraft and its operating agency. Types of AOC messages include the following:

- Weather Information
- Flight Plan Data
- Weight and Balance
- Pilot/Dispatcher Communications
- Flight Progress Information
- Position Information/Flight Following

- Maintenance Communication
- Gate Assignment
- In-Flight Emergencies
- Airframe/Avionics Monitoring Data
- Engine Monitoring Data
- Departure Delay Information
- Special Medical Requests
- Out-Off-On-In (OOOI) Information
- Checklists

Certain types of communication are not typically associated with AOC and are being accommodated on Aeronautical Enroute Service channels; these include de-icing and ramp control communications.

1.3.2.3 Aeronautical Administrative Communications (AAC)

AAC in the VHF band is only authorized in the domestic United States for data services in the AOC allotment. Aeronautical stations may transmit AAC messages on a secondary basis and AOC messages must be given absolute priority over AAC messages (47 CFR Section 87.265). Administrative communications must directly relate to the business of a participating aircraft operator in providing travel and transportation services to the flying public or to the travel, transportation or scheduling activities of the aircraft operator itself. Stations transmitting AAC must provide absolute priority for operational control and other safety communications by means of an automatic priority control system.

1.3.3 Digital Voice

A digital voice communications capability is a part of the system and shall satisfy the requirements for ATS and AOC services.

1.3.4 VDL Mode 3 Configuration Descriptions

The VDL Mode 3 architecture provides the flexibility to accommodate a range of operational requirements through a set of predefined system configurations. In the Air Traffic Control (ATC) environment the airspace is divided into distinct sectors. All the users in a sector form a user group and maintain a degree of mutual connectivity. A user group normally includes a ground user (e.g., an air traffic controller) and the client aircraft of that ground user. The services provided to a particular user group depend on the requirements of the sector and the capabilities of the ground system.

To meet the required degree of flexibility, different configurations provide different mixes of voice and/or data capabilities. At any given time different sectors can be supported by different configurations, and the configuration that applies in a particular sector is communicated to the aircraft radios through a beacon signal that is periodically broadcast by the ground station. It is expected that the configuration that applies to any given sector will be quasistatic and will not change often.

There are 4-slot configurations and 3-slot configurations. The applicability of these two basic types is range dependent as indicated in Table 3-52. The 4-slot configurations provide guard time sufficient to allow interference-free communication for up to 200 nautical miles (NM). For longer range scenarios, the 3-slot configurations can be used. Each of the configurations occupies one or more time slots available within one 25 kHz frequency assignment. In the descriptions below the phrase “independent voice and data” implies that up or down link voice communication and up or down link data communication can be occurring simultaneously (on a single platform) with no mutual interference.

The 4-slot configurations are:

4V	Provides a voice channel using 1 of the 4 time slots for each user group. A data capability is not provided. Can support up to 60 addressed aircraft per user group.
2V2D	Provides independent voice and data channels using one dedicated time slot for voice and one dedicated time slot for data for each user group. Can support up to 60 addressed aircraft per user group.
3V1D	Provides independent voice and data channels using one dedicated time slot for voice for each of the three user groups and a time slot shared by up to three of the user groups for data. Can support up to 60 addressed aircraft per user group.
3T	Provides a channel supporting voice and data using all (4) time slots. This is primarily a data channel in which voice communication is treated on a nearly equal basis as data, i.e., real-time voice access is not provided. Can support up to 180 aircraft in one (large) group.
1V3D	Provides independent voice and data using one time slot for voice and three time slots for data by a single user group. This is used to support sectors with more than 60 users that also require real-time voice service. Can support up to 240 addressed aircraft in one (large) user group.

The 3-slot configurations are:

3V	Provides a voice channel using 1 of the 3 time slots for each user group. A data capability is not provided. Can support up to 60 addressed aircraft per user group.
2V1D	Provides independent voice and data channels using one dedicated time slot for voice for each of the two user groups and a time slot shared by up to two of the user groups for data. Can support up to 60 addressed aircraft per user group.

3S	Provides a single voice channel using all (3) time slots. A data capability is not provided. This is used to support very large sectors in which three ground stations are required to provide complete coverage. Can support up to 60 addressed aircraft for the user group.
2S1X	Provides a single voice channel using 2 of the 3 time slots for one user group. The third time slot can be used to provide an independent channel for another user group. A data capability is not provided. This is used to support very large sectors in which two ground stations are required to provide complete coverage. Can support up to 60 addressed aircraft per user group.
1V2D	Provides independent voice and data using one time slot for voice and two time slots for data by a single user group. This is used to support sectors with more than 60 users that also require real-time voice service. Can support up to 240 addressed aircraft in one (large) user group.

Note: Overlapping sectors can use different configurations on the same 25 kHz frequency assignment provided that: (1) they all use either 3-slot or 4-slot configurations, (2) they don't use the same time slots, and (3) they are geographically compact enough so that time slot boundaries are not violated. For example, a 2V2D sector using slots A and C can be collocated with a 4V sector using slot B and another 4V sector using slot D.

1.4 System Interconnection and Routing

The new system will be used to provide authorized Aeronautical Mobile Services, voice and data, between users in aircraft and users on the ground.

1.4.1 Data

Figure 1-1 illustrates the connectivity for these users for ATN compatible data services wherein the system is depicted as the VHF Radio Subsystem, other subsystems required for end-user connectivity are the Avionics, Ground and User Subsystems.

The ATN concept encompasses all avionics, air-ground and ground communications facilities that would provide packet-mode data services between airborne mobile terminals and ground-based users. It is intended that this MASPS be consistent with ATN guidelines, to the extent that the reference points and interfaces correspond. It is expected that the system will support subnetwork specific data services, as well. Anticipated applications include FIS broadcasts.

1.4.2 Voice

Figure 1-2 illustrates the connectivity for these users for VDL Mode 3 voice services.

1.5 System Integration Considerations

A digital system design capable of providing both voice and data link on the same RF channel in a rapid sequential manner would allow a variety of ATS and AOC service provision arrangements to be implemented. A time division multiplexed system will satisfy a key design objective providing user access to both voice and data link capability. For example, a user with a single avionics unit could receive ATS voice and data link capabilities on a single RF channel. A full digital communications system could also allow automatic channel management to be accomplished from the ground. This would free the pilot from the labor intensive and error prone task of VHF communication channel tuning, while simultaneously reducing voice traffic.

1.6 Present VHF System

Currently, VHF radio is used primarily for voice communications. The signal-in-space is conventional double-sideband amplitude modulation (DSB-AM) with no carrier suppression.

Significant usage of digital data link over VHF channels has appeared in the decade of the 1980's. Internationally recognized standards exist for Aircraft Communications Addressing and Reporting System (ACARS)[1], and numerous service providers offer ground networks that are rapidly spreading throughout the world. A form of minimum-shift keying (MSK) modulation is used; however, full advantage of digital modulation is not realized because of the necessity of reducing the modulation to the audio baseband for interfacing with existing DSB-AM transmitters and receivers. This, coupled with the current VHF channelization, limits the channel data rate to approximately 4800 bps. Current ACARS avionics operate at a channel data rate of 2400 bps. Current VHF communications, voice and data, operate in simplex fashion; i.e., alternately transmit and receive on the same frequency. VHF radio is the mainstay of aeronautical communications, worldwide. Almost all civil aircraft, including the vast majority of the general aviation fleet, are equipped with at least one VHF voice radio.

VHF radio equipage is required of certain categories of aircraft, and of any aircraft type conducting particular operations in certain classes of airspace (for example, in Class B Airspace). VHF ground stations provide nearly complete coverage in most high-density regions of the world; nearly all commercial airports provide VHF radio services within their control zones. ACARS is a data link system which allows communication of character-oriented data between aircraft systems and ground systems. This communications facility enables the aircraft to operate as part of an airline's command, control and management system.

---

[1] ARINC Characteristics 597, 597A, 724, 724B. ARINC Specifications 618, 619, 620.

The portion of the system incorporated by the service provider's ground network and the equipment on board the aircraft are required to facilitate

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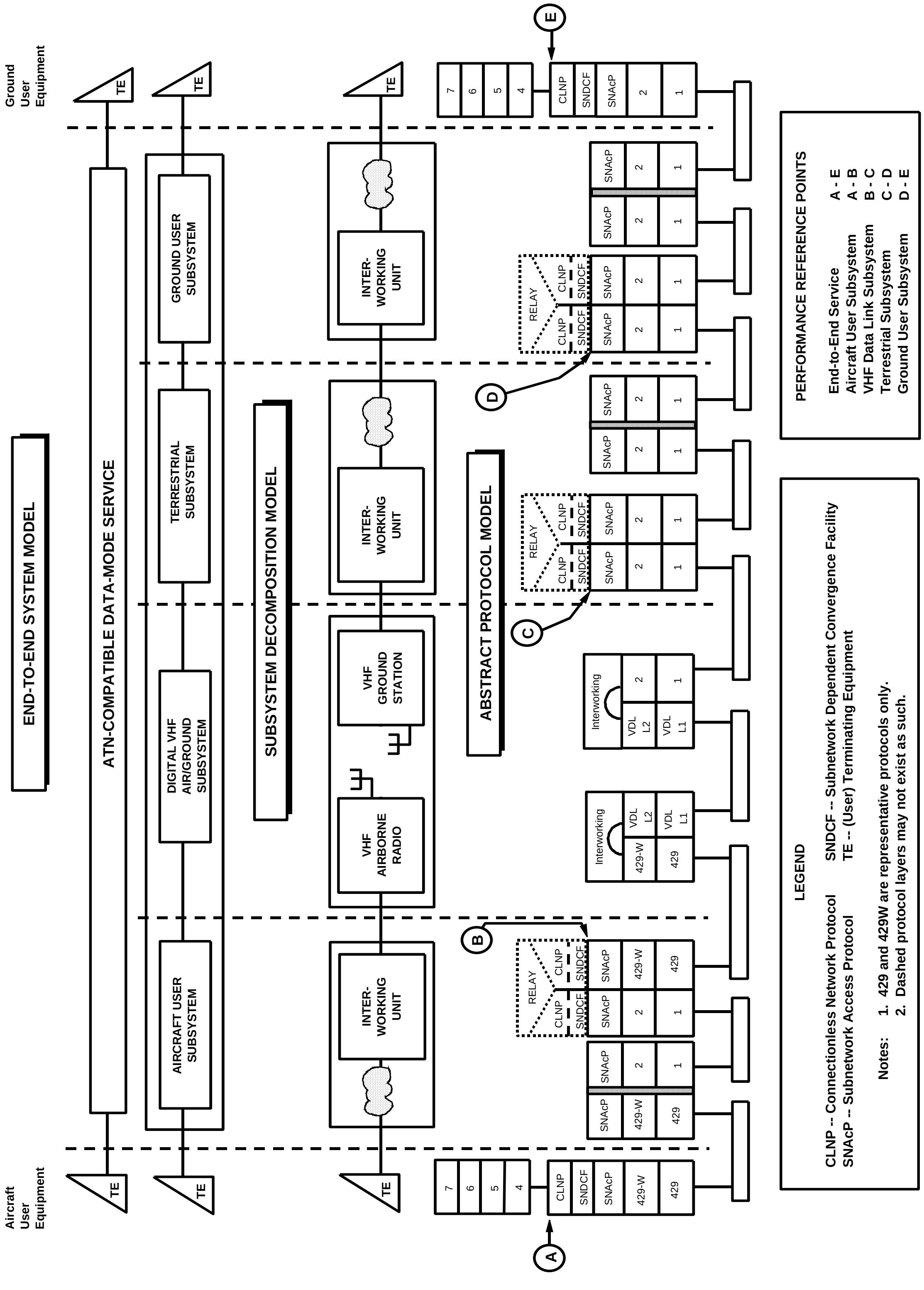
Aircraft User Equipment
Ground User Equipment
END-TO-END SYSTEM MODEL
ATN-COMPATIBLE DATA-MODE SERVICE
TE
AIRCRAFT USER SUBSYSTEM
DIGITAL VHF AIR/GROUND SUBSYSTEM
TERRESTRIAL SUBSYSTEM
GROUND USER SUBSYSTEM
SUBSYSTEM DECOMPOSITION MODEL
INTER-WORKING UNIT
VHF AIRBORNE RADIO
VHF GROUND STATION
ABSTRACT PROTOCOL MODEL
7
6
5
4
CLNP
SNDCF
SNAcP
429-W
429
2
1
RELAY
Interworking
VDL L2
VDL L1
A
B
C
D
E

LEGEND

CLNP -- Connectionless Network Protocol
SNAcP -- Subnetwork Access Protocol
SNDCF -- Subnetwork Dependent Convergence Facility
TE -- (User) Terminating Equipment

Notes: 1. 429 and 429W are representative protocols only.
2. Dashed protocol layers may not exist as such.

PERFORMANCE REFERENCE POINTS

End-to-End Service	A - E
Aircraft User Subsystem	A - B
VHF Data Link Subsystem	B - C
Terrestrial Subsystem	C - D
Ground User Subsystem	D - E

Figure 1-1: End-to-End ATN Compatible Data System Structure

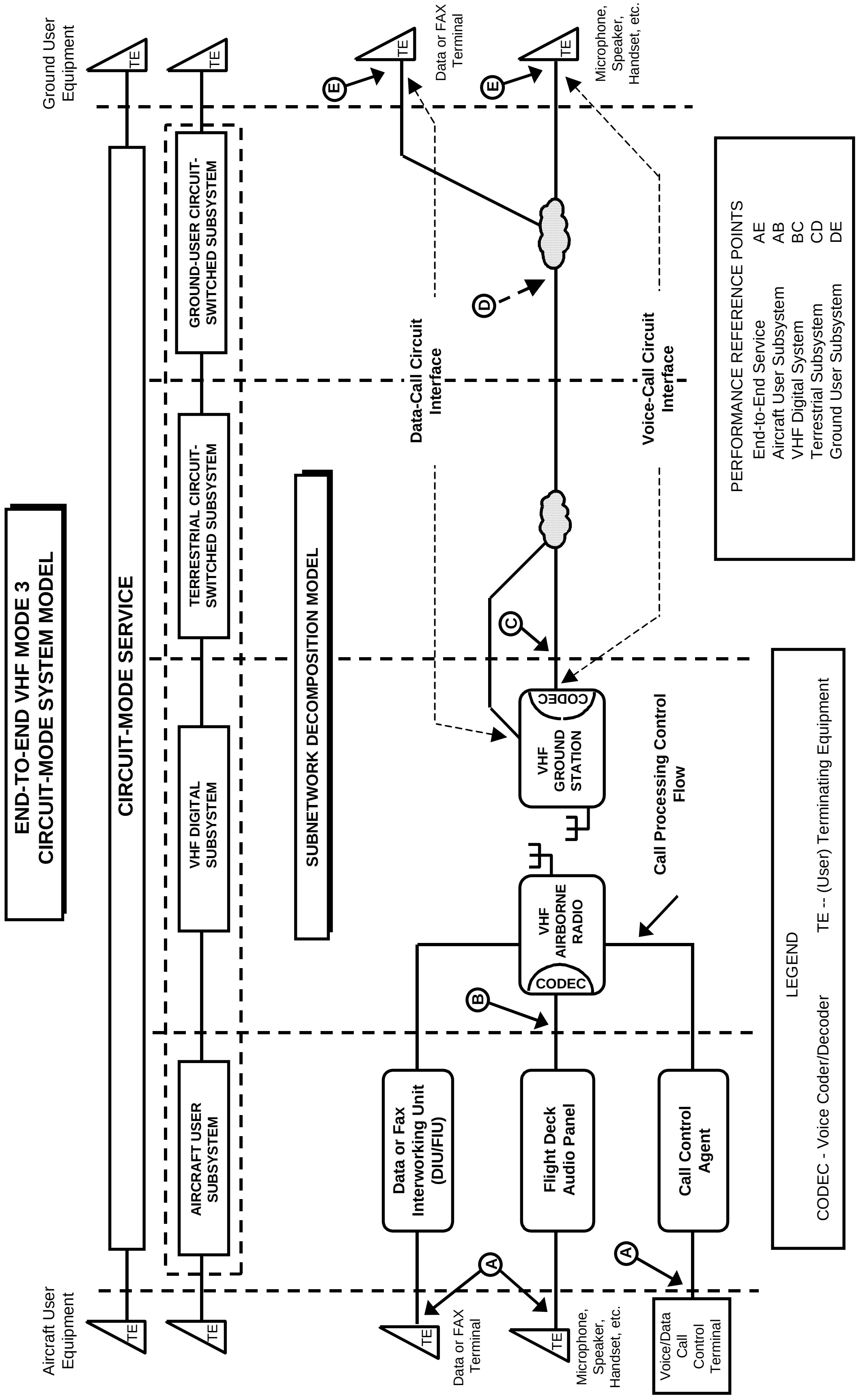
END-TO-END VHF MODE 3
CIRCUIT-MODE SYSTEM MODEL
CIRCUIT-MODE SERVICE
Aircraft User Equipment
Ground User Equipment
TE
AIRCRAFT USER SUBSYSTEM
VHF DIGITAL SUBSYSTEM
TERRESTRIAL CIRCUIT-SWITCHED SUBSYSTEM
GROUND-USER CIRCUIT-SWITCHED SUBSYSTEM
SUBNETWORK DECOMPOSITION MODEL
Data or Fax Interworking Unit (DIU/FIU)
Flight Deck Audio Panel
Call Control Agent
VHF AIRBORNE RADIO
CODEC
VHF GROUND STATION
Data-Call Circuit Interface
Voice-Call Circuit Interface
Call Processing Control Flow
A
B
C
D
E
Data or FAX Terminal
Microphone, Speaker, Handset, etc.
Voice/Data Call Control Terminal
PERFORMANCE REFERENCE POINTS
End-to-End Service AE
Aircraft User Subsystem AB
VHF Digital System BC
Terrestrial Subsystem CD
Ground User Subsystem DE
LEGEND
CODEC - Voice Coder/Decoder
TE -- (User) Terminating Equipment

Figure 1-2: VDL Mode 3 End-to-End Voice Services System Structure

the transfer of the messages. The ACARS service provider’s ground network comprises, as a minimum, an ACARS data link service processor and communications networks connecting the processor with the ground stations and ground users with the host system. The ground stations consist of a microcomputer connected to multiple VHF receivers and transmitters. The airborne equipment consists of an ACARS Management Unit (MU) which is connected to a VHF transceiver, a control/display (either dedicated or multi-purpose), and any ancillary equipment that supports the MU in its function, such as the Optional Auxiliary Terminal (OAT), Digital Flight Data Acquisition Unit (DFDAU) or cockpit printer.

1.6.1 Technical Description

ACARS is an air-ground communications network operating in the VHF aeronautical band. The ACARS consists of an airborne subsystem and a ground station network. The ground network is connected with the networks of subscribers. With the support of the ground-based service provider's network, the airborne part of the ACARS network enables equipment onboard an aircraft to function as a mobile communications terminal, performing as an integral part of a user's internal data communications system.

The format and protocols used to transfer messages between ACARS user's ground system and the Data Link Service Provider's (DLSP) network differs from the format and protocol used to exchange messages between the airborne user and the DLSP. The DLSP provides translation between these formats and message routing.

The format used to transmit messages between the ACARS ground user and the ACARS ground network is referred to as Standard Message Text (SMT), which uses Standard Message Identifiers (SMI) and Text Element Identifiers (TEI). The DLSP converts messages received from aircraft (downlink messages) into SMT format for consumption by the data link user, and transfers them to their ultimate destinations. Similarly, the DLSP converts messages received in SMT from the data link ground-based user into air-ground message formats having labels/sublabels and then pass the reformatted messages on to the airborne user.

The propagation characteristics of the VHF band restrict transmission and reception to essentially line-of-sight conditions. The maximum line-of-sight range for an enroute aircraft at an altitude of 30,000 feet is about 250 nautical miles. The radio range decreases at lower altitudes to a strictly localized coverage when the aircraft is on the ground. The normal index of refraction of the atmosphere is greater than unity, which extends the possible range of VHF transmissions most of the time. However, the refractivity varies widely, resulting in a significantly lower reliability of extended-range communications. The VHF radio channel is subject to slow and fast fading due to time varying multipath, obstruction of the radio line of sight, and changes in atmospheric conditions. The predominantly line-of-sight nature of VHF radio limits its use for air-ground and ground-air communications to airspace that can be served by land-based stations. Thus, coverage is limited to reasonably accessible over-land areas. Air-to-air communication is possible in any airspace, subject to the constraints of line-of-sight, transmitter effective radiated power, and receiver subsystem sensitivity.

Substantial reuse of VHF frequencies is made possible by line-of-sight characteristics. The degree of reuse possible is one of the key indicators of a system's capacity. In the ATC environment, which essentially operates in real time, reuse distance for a given frequency depends on the dimensions of the service volumes established for each ground station and the co-channel interference criteria. The airspace within defined service volumes provides protection from undesired signals. Figure 1-3 shows the basic geometry used for two service volumes that reuse the same frequency. For a simplex system, reuse distance is dictated by air-to-air interference between aircraft in opposing service volumes when aircraft are at their worst case "critical points." In a packet-based non-real time system such as ACARS, the same rules of reuse do not have to apply. Closer reuse of frequencies at ground stations can be achieved. Some cochannel interference can be tolerated because interference appears as a packet collision. The retry algorithms ensure the collided packets are retransmitted and received properly.

1.6.2 Deficiencies

The limitations of the current VHF system include:

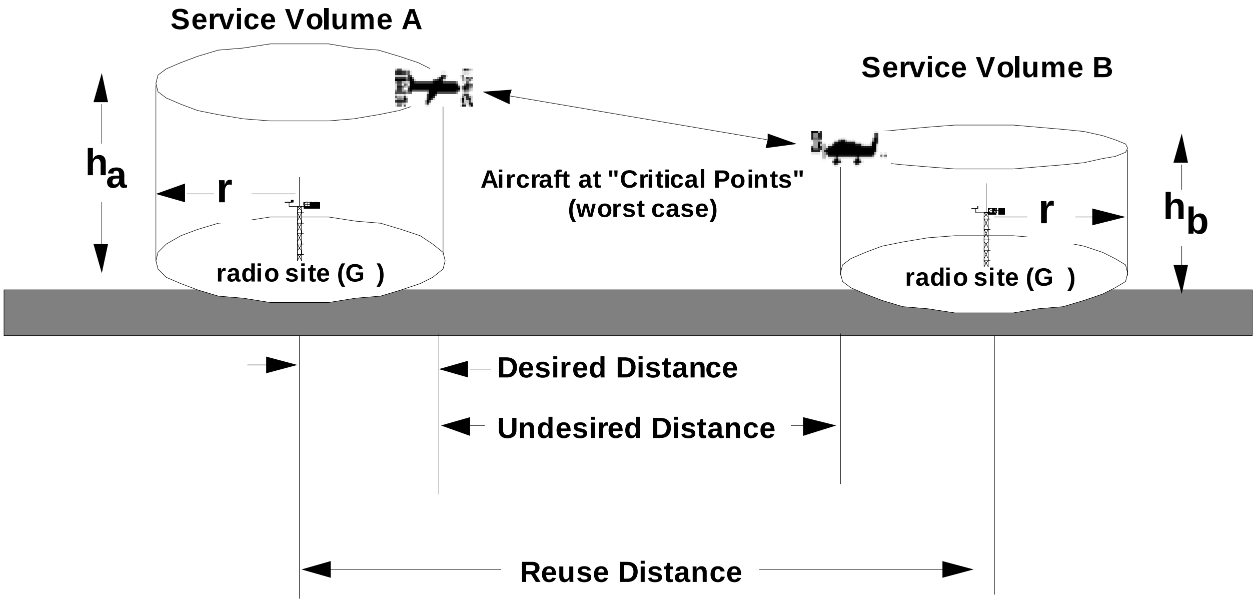

Figure 1-3: Establishing Reuse Distance in the ATC Environment

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a. Both voice and data modes are inefficient in their utilization of spectrum.
b. The quality of communications is subject to degradations due to various anomalies such as multipath fading, RF interference, and atmospheric disturbances.
c. Amplitude modulation is susceptible to various kinds of man-made radio frequency interference (RFI), including that from powerline noise, plastic welders, broadcast station interference and other RFI from transmitters of various kinds operating off frequency.
d. The present voice system has no degree of technical security or protection from intentional interference, such as "phantom controllers."
e. ACARS is a character-oriented system that is not compatible with modern compression technologies.
f. ACARS is not compatible with the Open System Interconnection (OSI) model prescribed for the ATN.
g. The ACARS Quality Of Service (QOS) cannot be readily improved.
h. Functionally simultaneous operation of the voice and data modes using a single avionics unit cannot be accomplished in an operationally acceptable manner.
i. A/G communications are susceptibile to stuck microphone blockage.
j. No mechanisms exist to control circuit access when multiple transmitters on the same frequency are keyed simultaneously.

2.0 AVIATION USER REQUIREMENTS

This section contains the broad requirements of the aviation users for a new VHF aeronautical communications system and their requirements during a transition period from the old to the new system.

2.1 System Users

The system shall be capable of supporting all categories of users including the following:

a. Scheduled air transport carriers (including international, trunk, regional, commuter and air freight carriers)
b. Non-scheduled air carriers
c. General aviation (including operators of turbine-powered and reciprocating engine aircraft)
d. Rotorwing aircraft (including helicopters and gyrocraft)
e. Unpowered aircraft (including gliders and lighter-than-air)
f. Military aircraft
g. Certain ground and maritime vehicles (e.g., airport service vehicles, those vehicles coordinating in a search-and-rescue mission)

2.2 Aircraft Characteristics

The system shall be capable of operation with appropriately-equipped aircraft of all types, and all flight regimes including at rest. There shall be no limitations imposed by the intrinsic characteristics of the ground system or the signal-in-space that limit suitable equipage of any type of aircraft, or for the following specific boundaries of flight conditions:

- Relative aircraft velocities	± 1,200 knots (two aircraft converging or diverging, each at 600 knots)
- Relative Ground speed	0 to 850 knots (600 knots aircraft speed plus 250 knots wind)
- Altitude	Ground Level to 70,000 feet above MSL

Notes:

1. *These do not include requirements for extremely high-speed aircraft (e.g., hypersonic transport).*

2. *Relative aircraft velocity is important for air-to-air communications among aircraft, for technical reasons (see Section 3.5.1.1).*

The new system shall provide no less coverage to maneuvering aircraft (roll, pitch, and yaw) than the existing VHF system.

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2.3 User Applications

The new system shall satisfy voice (speech) and data communications requirements for use in any authorized category of communications service, including ATS, AOC, and AAC.[2]

2.4 Availability and Integrity

2.4.1 Availability

The allocation of the availability and loss-of-service duration goals to the new system defined in this MASPS will depend on the architecture and availability characteristics of the overall system and subsystems (see Figures 1-1 and 1-2).

Notes:

1. *The service availability goal of the end-to-end communication system, of which the new system will be a part, is 0.99999 for voice service and 0.999 for data service. The goal for the duration of a single loss of service event in the end-to-end communications system is to be no more than 6 seconds. No single failure of equipment, system installation or facility will cause loss of service.*

2. *The new system will provide voice services equivalent to current ATC services which, if lost, would prevent the exercise of control for safe separation of aircraft. In the United States, the requirements of the National Airspace System (NAS) document SR-1000 apply to the ground equipment, where the category of service is Critical.*

3. *The airborne equipment is subject to availability and certification criteria that may differ from the above, and hence, is excluded from this paragraph.*

4. *The portion of the service availability allocated to the new system is for further study.*

---

[2] See RTCA SC-172 WG-1 Report on VHF Air-Ground Communications System Improvements Alternatives Study and Selection of Proposals for Future Action: DO-225, Chap. 3-AM(R)S, ATS and AOC Requirements.

2.4.2 Integrity

The integrity of the system is expressed in terms of Residual Packet Error Probability for data communications, and speech transmission quality for voice communications. The system shall provide the following integrity of communications requirements in the subnetwork: For data, with a packet length of 128 octets in length, the residual packet error rate shall be not greater than 10^{-6} in the to-aircraft direction, and not greater than 10^{-5} in the from-aircraft direction.

> *Note 1: Residual packet error rate includes misdelivery and non-delivery. The from-aircraft residual packet error rate is dominated by packets that may not be delivered in a timely manner in the system aircraft-to-ground link. Of the aircraft-to-ground packets successfully delivered, the undetected packet error rate should be not greater ~~that~~ than 10^{-6} at the MAC sublayer.*

Services requiring a greater degree of integrity can utilize additional error protection mechanisms; e.g., within the layers above the MAC sublayer of the protocol structure for data services.

For voice, the channel bit error rate shall be not greater than 10^{-3}.

> *Note 2: It is expected that the codec(s) used for digitized voice transmission in the system will be qualified to provide acceptable voice quality when presented a radio frequency (RF) channel bit error rate not greater than 10^{-3}.*

2.4.3 Continuity of Function

Continuity of function is defined as the probability that a communication system will operate without unscheduled interruptions over a specified exposure time, given that the communication system was operational when the exposure time interval was initiated.

The determination of the exposure time and the continuity characteristics of the overall system and the allocation of those characteristics to the VDL subsystem will be determined from the overall communication system requirements.

Note: The continuity of function value for voice communications must be equivalent to that currently provided for ATC voice services.

2.5 System Interoperability and Compatibility Requirements

The avionics equipment shall communicate with any compatible ground system. The new system shall be capable of implementation, installation and operation anywhere in the world.

The design of the system shall include capabilities to assure coexistence with the present analog voice system. The two systems must coexist over a transition period from analog-to-digital operations without compromising either ATS or AOC voice communications requirements.

The system shall support ATN compatible data services.

For digital voice operation, the system codec shall be capable of meeting all the voice channel access, voice message length, and voice quality requirements imposed by ATS and AOC.

To accommodate existing aircraft VHF communications equipment for an indefinite transition period, no degradation of existing VHF services shall be caused by any element of the system.

2.5.1 Provision of Digital Voice and Data Link

The system shall have a mode of operation capable of satisfying voice and data link requirements in a functionally simultaneous manner on a single RF channel. The ATS and AOC requirements do not have to be satisfied on the same RF channel. Functionally, simultaneous provision is interpreted to mean that the RF channel has the capability to provide the voice and data link communications in such a way that data and real time voice requirements are met.

2.5.2 Coexistence with Analog Voice

Analog voice will remain in the civil aviation system for many years to support the needs of many users. As these users are attracted to the benefits available in the new digital system, it is expected that there will be a gradual transition from analog to digital operations. In the meantime, however, it is recognized that analog users may not invest in digital equipment until it is in their best interest to do so, e.g., until the cost-benefit trade off is acceptable, or until the investment required to accomplish their operational objectives is recognized.

2.6 Delay

The transfer delay shall be measured between points B and C in Figure 1-1.

Note: Supporting material can be found in Appendix B.

2.6.1 VDL Mode 2

The VDL Mode 2 transfer delay shall not be greater than 3.5 seconds for the 95th percentile of the cumulative distribution.

Note: There are at least six basic components that comprise the overall time delay, D, of a data packet in a point-to-point context. Namely: Receive/transmit turnaround *time, packet transmission time, propagation time, processing time (including block interleaving and de-interleaving delays, coding and decoding delays, etc.), and access time which includes delays due to collisions with other packets in the transmission channel.*

2.6.2 VDL Mode 3

2.6.2.1 Data

As a design goal, high priority data messages of 192 application bits or less shall be delivered within one second with a probability of 0.95 and delivered within five seconds with a probability of 0.999.

2.6.2.2 Voice

Total voice delay shall be less than 236 ms between points B and C of Figure 1-2.

Note: Total voice delay between points A and E of Figure 1-2 is currently under review.

~~2.6.2.2 Voice~~

~~Total voice delay shall be less than 200 ms between points B and C of Figure 1-2.~~

~~*Note: Total voice delay between points A and E of Figure 1-2 should be less than 250 ms.*~~

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3.0 Technical Characteristics

The primary impetus for the development of this MASPS was derived from the pressing needs of civil aviation for a higher throughput data mode and compatibility with the ATN. It was also necessary to consider compatibility with future digital voice techniques to satisfy "real time" requirements. Accordingly, technical characteristics have been included, which span a range of performance capabilities. These are embodied in Section 3 by two basic modes called VDL Mode 2 and VDL Mode 3.

VDL Mode 2 is oriented toward statistical sharing of a channel. Depending on the applications and requirements, statistical sharing results in efficient channel utilization. On the other hand, VDL Mode 3 is intended to provide a more deterministic service performance for time critical applications.

The signal-in-space may be used for either or both modes of operation provided implementation is in accordance with VDL Mode 2 and VDL Mode 3 described herein and with industry standards. The definition, description, and specification of both modes are expected to continue to evolve as the industry, providers, and users further collaborate on future system concepts and capabilities.

3.1 Modes of Operation

VDL Mode 2 is appropriate for aperiodic traffic where the entire message is ready before transmission of individual message packets begins. VDL Mode 2 is not suitable for real-time applications such as real-time digital voice. (See definition of real-time in Section 1.1.2.)

VDL Mode 3 provides datalink and real-time voice operation and is able to guarantee delivery time within the slot/frame structure provided.

3.2 VDL Mode 2

3.2.1 Physical Layer Protocols and Services

The airborne and ground stations shall access the physical medium operating in simplex mode.

3.2.1.1 Functions

The physical layer shall provide the following functions:

1. Transceiver (or where physically separate, transmitter and receiver) frequency control
2. Data reception by the transceiver or receiver
3. Data transmission by the transceiver or transmitter
4. Notification services

3.2.1.1.1 Transceiver Frequency Control

The VDL physical layer shall set the transceiver (or where physically separate, transmitter and receiver) frequency as commanded by the link management entity (LME).

> *Note: The LME is a Link layer entity specified in Section 3.2.2.*

3.2.1.1.2 Data Reception by the Transceiver or Receiver

Signals received by the transceiver or receiver shall be decoded so that they may be accurately read at the higher layers.

3.2.1.1.3 Data Transmission by the Transceiver or Transmitter

The VDL physical layer shall appropriately encode the data received from the link layer and transmit it over the RF channel.

3.2.1.1.4 Notification Services

The operational status of the equipment shall be monitored at the physical layer. Signal quality analysis shall be performed on the demodulator evaluation process and on the receive evaluation process. This analysis shall be normalized between a scale of 0 and 15, where 0 to 3 is considered poor, 4 to 12 is adequate, and 13 to 15 is excellent.

Notes:

1. *Processes that may be evaluated in the demodulator include BER, SNR, and timing jitter. Processes that may be evaluated in the receiver include received signal level and group delay.*
2. *Receive evaluation processes may be based on the received signal strength.*
3. *Further development of performance monitoring is yet to be done.*

3.2.1.2 Modulation Scheme

The signal-in-space for VDL Mode 2 shall use differentially encoded 8 phase shift keying (D8PSK), using a raised cosine filter with $\alpha = 0.6$ (nominal value). The information to be transmitted shall be differentially encoded with 3 bits per symbol transmitted as changes in phase rather than absolute phase. The data stream to be transmitted shall be divided into groups of 3 consecutive data bits as described in Section 3.2.1.2.1. Zeros shall be padded to the end of the transmissions if needed for the final channel symbol.

The outputs of the baseband filters are applied to the inputs of ideal 4-quadrant multipliers whose RF inputs are driven in quadrature by RF at the desired transmitting frequency. The outputs of the two multipliers are summed in-phase to provide the transmitted signal. The resulting signal has eight equal amplitude states with an angular spacing of Π/4 radians.

> Note 1: *The above method describes a means of generating the desired signal-in-space. Other methods that provide equivalent results may be used.*

Because of amplitude variation of the composite signal, any amplification following the modulation process must be sufficiently linear so as to provide the adjacent channel performance in Section 3.2.1.10.3.

> Note 2: *The above chosen for no more than 1 dB transmitter implementation loss.*

3.2.1.2.1 Data Encoding

A binary data stream entering a differential data encoder shall be converted into three separate binary streams X, Y, and Z so that bits 3n form X, bits 3n+1 form Y, and bits 3n+2 form Z. The triplet at time k (X_k, Y_k, Z_k) shall be converted to a change in phase as shown in Table 3-1, and the absolute phase N_k is the accumulated series of $)N_k$, that is:

$$N_k = N_{k-1} +)N_k$$

Table 3-1: Data Encoding

X_k	Y_k	Z_k	$)N_k$
0	0	0	0 B / 4
0	0	1	1 B / 4
0	1	1	2 B / 4
0	1	0	3 B / 4
1	1	0	4 B / 4
1	1	1	5 B / 4
1	0	1	6 B / 4
1	0	0	7 B / 4

> Note: *See the ICAO VDL SARPs Implementation Aspects.*

3.2.1.2.2 Transmitted Signal Form

The phase-modulated baseband signal, as defined in Section 3.2.1.2.1, shall excite the pulse shape filter.

$$s(t) = \sum_{k=-\infty}^{\infty} h(\varphi_k, t - kT_s)$$

where:

h( )	is the complex impulse response of the pulse shape filter.
k	is defined in paragraph 3.2.1.2.1.
φ	is defined in paragraph 3.2.1.2.1.
t	is time.
T_s	is time duration of each symbol.

The output (function of time) of the pulse shape filter shall modulate the carrier frequency. The pulse shape filter shall have a nominal complex frequency response of a raised-cosine filter with =0.6.

The Error Vector Magnitude (EVM) of the transmitter output should be less than 6% rms, which corresponds to a transmitter implementation loss of approximately 1 dB.

3.2.1.2.3 Modulation Rate

The symbol rate shall be 10,500 symbols/sec ± 0.005%, resulting in a nominal bit rate of 31,500 bps.

3.2.1.2.4 Emission Designator

The emission designator of this modulation technique for CSMA is 14K0G1DE where:

14K	is 14 kHz occupied bandwidth
G	is Phase modulation
1	is Single channel digital with no modulating sub carrier
D	is Data transmission
E	is Multi-condition code

Note: *See the CFR (Code of Federal Regulations) 47 Part 2, Subpart C, Emissions, Sections 2.201 and 2.202.*

3.2.1.2.5 Pulse Shaping Filters

The frequency and time response of the baseband filters is defined as:

$$H(f) = \begin{cases} 1 & 0 < f \le \dfrac{1-\alpha}{2T} \\ \dfrac{1 - \sin\left(\dfrac{\Pi}{2\alpha}(2fT - 1)\right)}{2}, & \dfrac{1-\alpha}{2T} \le f \le \dfrac{1+\alpha}{2T} \\ 0 & f > \dfrac{1+\alpha}{2T} \end{cases}$$

and the impulse response of

$$h(t) = \frac{\sin\left(\dfrac{\Pi t}{T}\right)}{\dfrac{\Pi t}{T}} \frac{\cos\left(\dfrac{\Pi \alpha t}{T}\right)}{1 - \left(\dfrac{2\alpha t}{T}\right)^2}$$

where *f* is the absolute value of the frequency offset from the channel center, T is the symbol period of 1/10500 sec (or approximately 95.2 µsec), and ∀ is 0.6.

3.2.1.3 Training Sequence

Data transmission shall begin with a demodulator training sequence consisting of five segments:

- Transmitter power stabilization and Receiver AGC Settling
- Synchronization and ambiguity resolution
- Reserved symbol
- Transmission length
- Header FEC

> Note: *Immediately after these segments there is an Aviation VHF Link Control (AVLC) frame with the format specified in 3.2.2.4.2.1.*

3.2.1.3.1 Transmitter Ramp-up and Power Stabilization

The purpose of the first segment of the training sequence, called the ramp-up, is to provide for transmitter power stabilization and receiver AGC settling and it shall immediately precede the first symbol of the unique word. The duration of the ramp-up shall be five symbol periods. However to facilitate symbol measurement, the time reference point (t) for the following specification is the center of the first unique word symbol, which occurs ½ symbol period after the end of the ramp-up.

Conversely stated, the beginning of the ramp-up starts at t = -5.5 symbol periods.

The transmitted power shall be less than –40 dBc prior to time t = -5.5 symbol periods. The ramp-up shall provide that at time t = -3.0 symbol periods the transmitted power is 90% of the manufacturer's stated output power or greater. Regardless of the method used to implement (or truncate) the raised cosine filter, the output of the transmitter between times t = -3.0 and t = -0.5 will appear as if '000' symbols were transmitted during the ramp-up period.

Figure 3-1 illlustrates the transmitter ramp-up and power stabilization.

Notes:

1. *For VDL Mode 3, the timing reference point is the same as the "Power Reference Point".*

2. *It is desirable to maximize the time allowed for the AGC settling time. Efforts should be made to have power above 90% of nominal output power at t = -3.5 symbol periods.*

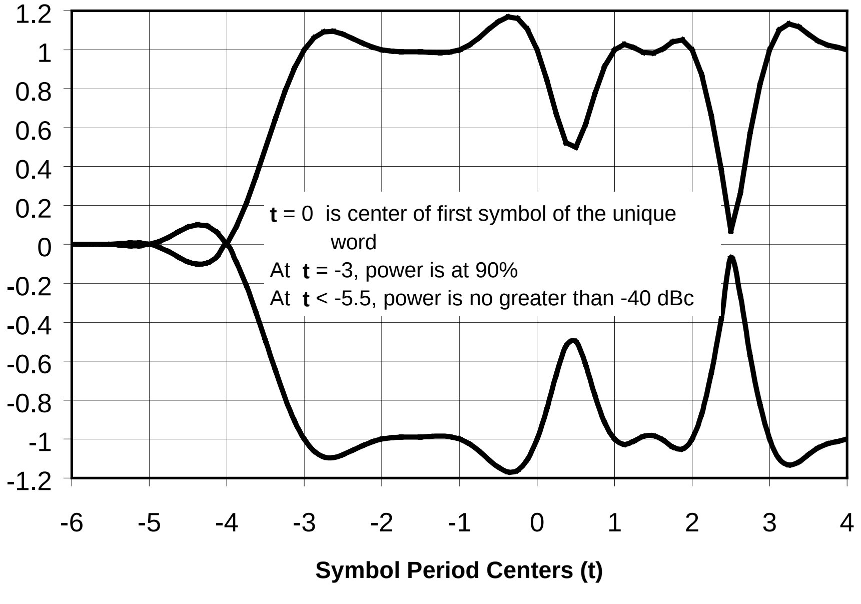

Figure 3-1: Transmitter Power Stabilization

3.2.1.3.2 Transmitter Power Ramp Down

The transmitter power shall be below –20 dBc within 2.5 symbol periods of the middle of the final symbol of the burst.

The transmitter power leakage when the transmitter is in the "off" state shall be less than –83 dBm.

> *Note: Reference DO-160D Section 21, category H for antenna radiated signals.*

3.2.1.3.3 Synchronization and Ambiguity Resolution

The second segment of the training sequence shall consist of the unique word:

000 010 011 110 000 001 101 110 001 100 011 111 101 111 100 010

and shall be transmitted from left to right.

3.2.1.3.4 Reserved Symbol

The third segment of the training sequence shall consist of the single symbol representing 000.

> *Note: This field is reserved for future definition.*

3.2.1.3.5 Transmission Length

To allow the receiver to determine the length of the final Reed-Solomon (RS) block, the transmitter shall send a 17-bit word as the fourth segment, from least significant bit (LSB) to most significant bit (MSB), indicating the total number of data bits that follow the header FEC.

> *Note: The length does not include those bits transmitted for: the Reed Solomon FEC, extra bits padded to ensure that the interleaver generates an integral number of 8-bit words, or the extra bits padded to ensure that the data encoder generates an integral number of 3-bit symbols.*

3.2.1.3.6 Header FEC

To correct bit errors in the header, a (25, 20) block code shall be computed over the reserved symbol and the transmission length segments. The block code shall be transmitted as the fifth segment. The encoder shall accept the header in the bit sequence that is being transmitted. The five parity bits to be transmitted shall be generated using the following equation:

$$[P_1,\ldots,\ P_5] = [R_1,\ldots,\ R_3, TL_1,\ldots, TL_{17}]\ H^T$$

Where:

P	is the parity symbol. (P_1 shall be transmitted first.)
R	is the reserved symbol.

TL is the transmission length symbol.
^{T} is the matrix transpose function.
H is the parity matrix defined below.

$$H = \begin{matrix} 0&0&0&0&0&0&0&0&1&1&1&1&1&1&1&1&1&1&1&1 \\ 0&0&1&1&1&1&1&1&0&0&0&0&1&1&1&1&1&1&1&1 \\ 1&1&0&0&0&1&1&1&0&0&1&1&0&0&0&0&1&1&1&1 \\ 1&1&0&1&1&0&1&1&0&1&0&1&0&0&1&1&0&0&1&1 \\ 0&1&1&0&1&0&0&1&1&1&1&0&0&1&0&1&0&1&0&1 \end{matrix}$$

3.2.1.3.7 Bit Transmission Order

The five parity bits of the resultant vector product shall be transmitted from the left bit first.

3.2.1.4 Error Correction Encoding Techniques

3.2.1.4.1 Error Correction Encoding of Data

Forward Error Correction (FEC) coding shall be applied to digital data communication traffic.

3.2.1.4.2 Error Detection Encoding of Data

Error detection encoding shall be achieved by the Cyclic Redundancy Check (CRC). A 16-bit field is used for the CRC in each codeword. The generator polynomial (CRC-CCITT) for this code is $g(x) = 1 + x^5 + x^{12} + x^{16}$.

3.2.1.4.3 Forward Error Correction

In order to improve the effective channel throughput by reducing the number of required retransmissions, FEC shall be applied after the training sequence, regardless of the AVLC frame boundaries.

3.2.1.4.3.1 FEC Calculation

The FEC coding shall be accomplished by means of a systematic fixed-length Reed-Solomon (255, 249) 2^8-ary code.

> Note: *This code is capable of correcting up to three octets for data blocks of 249 octets (1992 bits). Longer transmissions must be divided up into 1992 bit transmissions and shorter transmissions must be extended by virtual fill with trailing zeros. Six RS-check octets are appended for a total block of 255 octets.*

The field defining primitive polynomial of the code shall be as follows:

$$p(x) = (x^8 + x^7 + x^2 + x + 1)$$

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The generator polynomial for VDL Mode 2 only shall be as follows:

$$\prod_{i=120}^{125}(x-\alpha^{i})$$

Where:

∀	is a primitive element of GF(256), and
GF(256)	is a Galois field (GF) of size 256.

Notes:

1. *The Reed-Solomon codes are described in the Recommendation for Space Data System Standards: “Telemetry Channel Coding," by the Consultative Committee for Space Data Systems.*

2: *See appendix E for more information on Reed Solomon coding.*

3.2.1.4.3.2 Block Lengths

The six RS-check octets shall be calculated on blocks of 249 octets. Longer transmissions shall be split into blocks of 249 octets, per Section 3.2.1.5. Blocks of shorter length shall be extended to 249 octets by a virtual fill of trailing zeroes. The virtual fill shall not be transmitted. Blocks shall be coded according to Sections 3.2.1.4.3.2.1 through 3.2.1.4.3.2.4.

3.2.1.4.3.2.1 No Error Correction

For blocks with 2 or fewer non-fill octets, no error correction shall be used.

3.2.1.4.3.2.2 Single-Byte Error Correction

For blocks with 3 to 30 non-fill octets, all six RS-check octets shall be generated, but only the first two shall be transmitted. The last four RS-check octets shall be treated as erasures at the decoder.

3.2.1.4.3.2.3 Two-Byte Error Correction

For blocks with 31 to 67 non-fill octets, all six RS-check octets shall be generated, but only the first four shall be transmitted. The last two RS-check octets shall be treated as erasures at the decoder.

3.2.1.4.3.2.4 Three-Byte Error Correction

For blocks with 68 or more non-fill octets, all six RS-check octets shall be generated and transmitted.

3.2.1.5 Interleaving

To improve the performance of the FEC, an octet based table-driven interleaver shall be used. The interleaver shall create a table having 255 octets per row and c columns, where:

c = Ceiling [transmission_length_per_Section_3.2.1.3.4 / 1992 bits].

After extending the data to a multiple of 1992 bits, the interleaver shall write the transmission stream into the first 249 octets of each row by taking each consecutive group of eight bits and storing them from the first column to the 249th. The first bit in each group of eight bits shall be stored in the eighth bit position; the first group of 1992 bits shall be stored in the first row, the second group of 1992 bits in the second row, etc. After the FEC is computed on each row, the FEC data (or erasures) shall be stored in columns 250 through 255. The interleaver shall then pass the data to the scrambler by reading out column by column, skipping any octet that contains erasures or all fill bits. All of the bits in an octet shall be transmitted from bit 8 to bit 1.

On reception, the de-interleaver shall calculate the number of rows and size of the last (potentially partial) row from the length field in the header. It shall only pass valid data bytes to the higher layer.

The maximum value of (c) shall be 66.

3.2.1.6 Bit Scrambling

To aid clock recovery and to stabilize the shape of the transmitted spectrum, bit scrambling shall be applied. The pseudo noise (PN) sequence shall be a 15 - stage generator (see Figure 3-2) with the characteristic polynomial:

$$X^{15} + X + 1$$

The PN-sequence shall start after the frame synchronization pattern with the initial value 1101 0010 1011 001 with the left-most bit in the first stage of the register per Figure 3-2. After processing each bit, the register shall be shifted one bit to the right.

The sequence shall be added (modulo 2) to the data at the transmit side (scrambling) and to the scrambled data at the receive side (descrambling) per Table 3-2.

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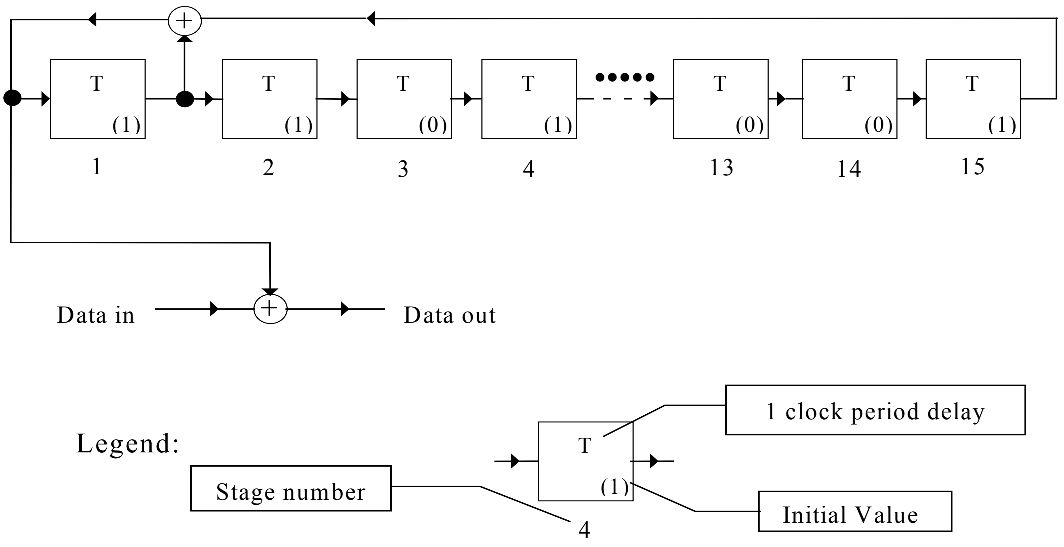

T
(1)
1
T
(1)
2
T
(0)
3
T
(1)
4
T
(0)
13
T
(0)
14
T
(1)
15
Data in
Data out
Legend:
Stage number
T
(1)
4
1 clock period delay
Initial Value

Figure 3-2: PN Generator for BIT Scrambling Sequence

Table 3-2: Scrambler Functions

Function	Data in	Data out
Scrambling	Clean data	Scrambled data
Descrambling	Scrambled data	Clean data

Notes:

1. *The concept of a PN scrambler is explained in the International Radio Consultative Committee (CCIR) Report 384-3, Annex III, Section 3, Method 1.*

2: *See Appendix F for a VDL Mode 2 message example.*

3.2.1.7 Channel Sensing

For the purposes of channel sensing, all signal levels shall be referenced to the receiver input. This will allow a Systems Planner to predict performance in a given environment.

Note: Further empirical development of channel sensing requirements is yet to be done.

3.2.1.7.1 Channel Busy to Idle Detection

When a station receives on-channel power of at least minus 95 dBm ±2 dB for at least 5 ms without detecting a sync sequence and successfully decoding the header, then:

1. with a likelihood of 0.9, it shall continue to consider the channel occupied if the signal level is attenuated to below minus 100 dBm ±2 dB for less than 1 ms; and
2. with a likelihood of 0.9, it shall consider the channel unoccupied if the signal level is attenuated to below minus 100 dBm ±2 dB for at least 1.5 ms

If a station has received a sync sequence and successfully decoded the header, it shall not consider the channel idle until the recovered message length has expired even if the RF signal drops below the RF sense level during this period.

Note: The maximum link throughput available to all users is highly sensitive to the RF channel sense delay (from the time when the channel actually changes state until a station detects and acts on that change) and RF channel seizure delay (from the time when a station decides to transmit until the transmitter is sufficiently ramped up to lock out other stations). Accordingly, it is imperative that all efforts are made to reduce those times as the sate-of-the-art advances.

3.2.1.7.2 Channel Idle to Busy Detection

With a likelihood of at least 0.9, a station shall consider the channel occupied within 1 ms after on-channel power rises to at least minus 98dBm ±2 dB.

Notes:

1. The goal to detect an occupied channel is detection within 0.5 ms.
2. A higher probability of false alarm is acceptable on the idle-to-busy detection than the busy to idle detection because of the effects of the two different errors.

3. Provision should be made for possible future incorporation of adjustable channel sense decision powers in the range of ± 5dB of the default values to allow for system optimization on individual platforms. **~~3.2.1.7 Channel Sensing~~**

~~*Note: Further empirical development of channel sensing requirements is yet to be done.*~~

~~3.2.1.7.1 Channel Busy to Idle Detection~~

~~When a station receives on-channel power of at least -87 dBm for at least 5 ms, then:~~

~~1. with a likelihood of 0.9, it shall continue to consider the channel occupied if the signal level is attenuated to below -92 dBm for less than 1 ms; and~~
~~2. with a likelihood of 0.9, it shall consider the channel unoccupied if the signal level is attenuated to below -92 dBm for at least 1.5 ms.~~

Note: ~~The maximum link throughput available to all users is highly sensitive to the RF channel sense delay (from the time when the channel actually changes state until a~~

~~*station detects and acts on that change) and RF channel seizure delay (from the time when a station decides to transmit until the transmitter is sufficiently ramped up to lock out other stations). Accordingly, it is imperative that all efforts are made to reduce those times as the state-of-the-art advances.*~~

~~3.2.1.7.2 Channel Idle to Busy Detection~~

~~With a likelihood of at least 0.9, a station shall consider the channel occupied within 1 ms after on-channel power rises to at least -90 dBm.~~

~~*Notes:*~~

~~*1. The goal to detect an occupied channel is detection within 0.5 ms.*~~

~~*2: A higher probability of false alarm is acceptable on the idle to busy detection than the busy to idle detection because of the effects of the two different errors.*~~

3.2.1.8 Physical Layer System Parameter

The parameter P1 shall be the maximum transmission length that a receiver is capable of demodulating without degradation of BER. Maximum transmission length shall be 131,071 bits.

3.2.1.9 Receiver/Transmitter Interactions

Refer to Figure 3-3 for turnaround requirements.

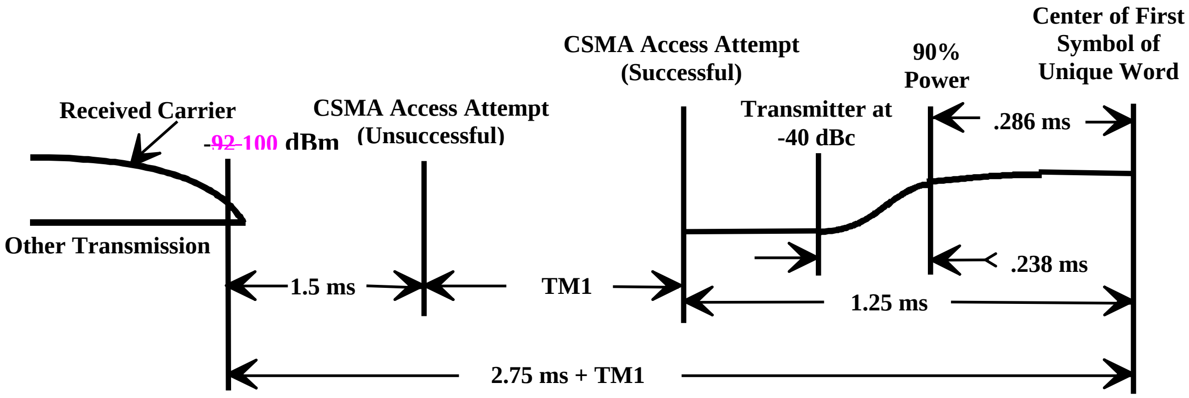
3.2.1.9.1 Receive to Transmit Turnaround Time

A station shall transmit the training sequence such that the center of the first symbol of the unique word will be transmitted within 1.25 ms after the result of an access attempt is successful. The maximum frequency change over the sync preamble shall be 100 Hz. This will give a spread of 3.4 degrees over the synchronization sequence. The frequency over the transmission should stay within the ± 5 ppm limits. The frequency has to be measured by averaging over a 10 ms time period. The frequency shall change at a rate of no more than 1000 Hz per second, to allow a frequency-tracking loop in the receiver to keep the frequency error at the demodulator sufficiently small.

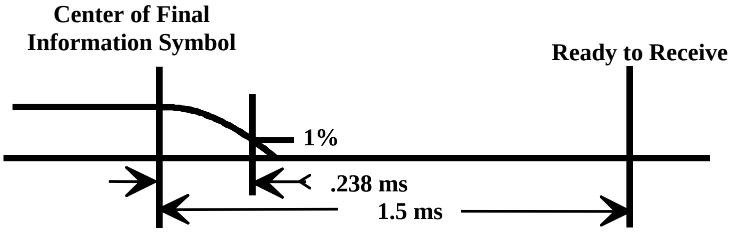
Note: *As an example, a phase acceleration of 1000 Hz per second corresponds to 60 Hz sidebands at a level of –33 dBc. Shorter-term frequency variations are covered by the transmitter phase-error specification.*

3.2.1.9.2 Transmit to Receive Turnaround Time

A station shall be capable of receiving and demodulating, with nominal performance, an incoming signal within 1.5 ms after transmitting the final information symbol.


Center of First Symbol of Unique Word
CSMA Access Attempt (Successful)
90% Power
Received Carrier
CSMA Access Attempt (Unsuccessful)
Transmitter at -40 dBc
.286 ms
-~~92~~ 100 dBm
Other Transmission
.238 ms
1.5 ms
TM1
1.25 ms
2.75 ms + TM1

Receive to Transmit Requirements


Center of Final Information Symbol
Ready to Receive
1%
.238 ms
1.5 ms

Transmit to Receive Requirements

Figure 3-3: Turnaround Time

3.2.1.10 Transmission Characteristics

3.2.1.10.1 Carrier Frequencies

The system shall be capable of operating on 25 kHz center frequencies in the 117.975 MHz to 137 MHz frequency band.

3.2.1.10.2 Spurious Emissions

Spurious emissions (see Section 1.1.2 for definition) shall be in accordance with the Code of Federal Regulations, Title 47 (47 CFR), Federal Communications Commission.

> Note: *The FCC spurious emissions requirement of -40 dBc may not protect GPS navigation receivers on the same aircraft from harmful interference because more than 100 dB of additional attenuation is required. Of*

particular concern are VHF 12th and 13th harmonics (especially 121.150, 121.175, 121.2, 131.2, 131.25, and 131.3 MHz). Spurious emissions from the VHF antenna and from the VHF box itself can be a problem. Additional filtering and shielding may be required to protect navigation receivers on the same aircraft. Intersystem electromagnetic compatibility issues are beyond the scope of this document at this time.

Section 3.2.1.10.3 Adjacent Channel Emissions

The RF power measured over a 16 kHz channel bandwidth centered on the first adjacent channel shall not exceed minus 18 dBm.

The RF power measured over a 25 kHz channel bandwidth centered on the first adjacent channel shall not exceed plus 2 dBm.

The RF power measured over a 25 kHz channel bandwidth when centered on either the second adjacent channel or the third adjacent channel shall not exceed minus 28 dBm.

The RF power measured over a 25 kHz channel bandwidth centered on the fourth adjacent channel shall not exceed minus 38 dBm.

Beyond the fourth adjacent channel, the RF power measured in a 25 kHz channel bandwidth shall reduce at a minimum rate of 5 dB per octave from the fourth adjacent channel on, to a maximum value of minus 53 dBm.

Note: The adjacent channel power requirements apply over the entire 117.975 - 137 MHz VHF band.

The adjacent channel specifications of this section shall be met over normal VDL operating conditions, including transmitter attack and decay transients occurring at the beginning and end of VDL bursts.

~~3.2.1.10.3 Adjacent Channel Emissions~~

~~The amount of power from a transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 2 dBm. The amount of power from a transmitter under all operating conditions when measured over a 16 kHz channel bandwidth centered on the first adjacent channel shall not exceed -18 dBm.~~

~~The amount of power from a transmitter under all operating conditions when measured over the 25 kHz channel bandwidth centered on the second adjacent channel shall be less than -28 dBm. For the fourth adjacent channel the power shall be less than -38 dBm and it shall decrease at the rate of no less than 5 dB per octave to less than -53 dBm.~~

~~*Notes:*~~

~~*1. Reference RTCA DO-160C, Section 21.*~~

~~2. It is the objective of the FAA to achieve an adjacent channel frequency assignment criterion as close as possible to the present 0.6 nautical miles, and to have no frequency assignment constraints on second adjacent channels and beyond.~~

3.2.2 Link Layer Protocols and Services

3.2.2.1 Structure

The VHF Digital Link (VDL) Mode 2 link layer shall provide the following sublayer functions:

1. A Media Access Control (MAC) sublayer which requires the use of the carrier sense multiple access (CSMA) algorithm
2. A Data Link Service (DLS) sublayer, providing connection-oriented point-to-point links using Data Link Entities (DLE) and a connectionless broadcast link over the MAC sublayer
3. A VDL Management Entity (VME), which establishes and maintains DLEs between airborne and ground stations using Link Management Entities (LME)

3.2.2.2 Service

3.2.2.2.1 Connection-Oriented

The VDL link layer shall provide a reliable point-to-point service using a connection-oriented DLS sublayer.

3.2.2.2.2 Connection-Less

The VDL link layer shall provide an unacknowledged broadcast service using a connectionless DLS sublayer.

3.2.2.3 MAC Sublayer

The MAC sublayer shall provide for the transparent acquisition of the shared communications path. It makes invisible to the DLS sublayer the way in which supporting communications resources are utilized to achieve this.

Note: *The service specification for the MAC sublayer is modeled on the MAC Service Definition (ISO DP 10039).*

3.2.2.3.1 MAC Services

3.2.2.3.1.1 Multiple Access

The MAC sublayer shall implement a non-adaptive p-persistent CSMA algorithm to equitably allow all stations the opportunity to transmit while maximizing system throughput, minimizing transit delays, and minimizing collisions.

3.2.2.3.1.2 Channel Occupancy

The maximum channel occupancy time of a station shall be limited by the window size, data rate, and maximum frame size. A VDL Mode 2 station shall be able to hold the channel for the time required to transmit k - 1 maximum size data frames at the current data rate.

Note: See Section 3.2.2.4.3.7 for definition of k.

3.2.2.3.1.3 Channel Congestion

The MAC sublayer shall notify the VME sublayer whenever channel congestion is detected. (See Section 3.2.2.3.2.2)

3.2.2.3.2 MAC Service System Parameters

The MAC service shall implement the system parameters defined in Table 3-3.

Table 3-3: MAC Service System Parameters

Symbol	Parameter Name	Lower Bound	Upper Bound	Default	Increment
TM1	Inter-access Delay	0.5 msec	125 msec	4.5 msec	0.5 msec
TM2	Channel Busy	6 sec	120 sec	60 sec	1 sec
p	Persistence	1/256	1	13/256	1/256
M1	Maximum Number of Access Attempts	1	65535	135	1

3.2.2.3.2.1 Timer TM1 (Inter-access Delay Timer)

The TM1 timer shall be set to the time (TM1) that a MAC sublayer will wait between consecutive access attempts (see Section 3.2.2.3.3.2). This timer shall be started if it is not already running and the channel is idle after an access attempt is unsuccessful. The timer shall be canceled if the channel becomes busy. When the timer expires, another access attempt shall be made.

3.2.2.3.2.2 Timer TM2 (Channel Busy Timer)

The TM2 timer shall be set to the maximum time (TM2) that a MAC sublayer will wait after receiving a request to transmit. This timer shall be started, if it is not already running, when the MAC sublayer receives a request for transmission. The timer shall be canceled upon a successful access attempt. When the timer expires, the VME shall be informed that the channel is congested.

3.2.2.3.2.3 Parameter p (Persistence)

The parameter *p* (0 < *p* ≤1) shall be the probability that the MAC sublayer will transmit on any access attempt (see Section 3.2.2.3.3.2).

3.2.2.3.2.4 Counter M1 (Maximum Number of Access Attempts)

The M1 counter shall be set to the maximum number of attempts (M1) that a MAC sublayer will make for any transmission request. This counter shall be reset upon: system initialization, Timer TM2 expiring, or a successful access attempt. The counter shall be incremented after every unsuccessful access attempt. When the counter expires, authorization to transmit shall be granted as soon as the channel is idle.

3.2.2.3.3 Description of Procedures

3.2.2.3.3.1 Channel Sensing

Before performing an access attempt (see Section 3.2.2.3.3.2), the MAC sublayer shall verify that the channel is idle.

3.2.2.3.3.2 Access Attempt

An access attempt is defined as the MAC layer determining whether the transmitter should be immediately enabled, with probability *p*. The result of an access attempt will be either *successful* or *unsuccessful*. If the access attempt is successful then the transmission shall immediately begin.

An access attempt shall be made when Timer TM1 expires and the channel is idle or when a transmission request arrives from the DLS while the channel is idle or if the channel is determined to become idle while a message is queued for transmission.

3.2.2.4 Data Link Service Sublayer

The DLS shall support bit-oriented simplex air/ground (A/G) communications using the Aviation VHF Link Control (AVLC) protocol specified in this section.

> *Note**: The DLS is derived from HDLC, as specified by ISO 3309, ISO 4335, ISO 7809, and ISO 8885. Any definitions of service are derived from the OSI Data Link Service Definition ISO 8886.3. AVLC is a variant of HDLC and derived from, but is not fully specified by, options 1, 3.2, 4, 7, and 12 of ISO 7809. Explicit*

references to these documents are made later in this section.

3.2.2.4.1 Services

Note: *In this section, the specific functions of the DLS are described with no reference to service primitives used for these functions. The link layer service primitives and protocol state machine are described in the ICAO VDL SARPs Implementation Aspects for VDL Mode 2.*

3.2.2.4.1.1 Frame Sequencing

The receiving DLS sublayer shall ensure that duplicated frames are discarded and all frames are delivered exactly once over a point-to-point connection.

Note: *Sequence numbers are included in the frame format to facilitate this service.*

3.2.2.4.1.2 Error Detection

The DLS sublayer shall ensure that frames that failed the Frame Check Sequence (FCS) shall be discarded.

Note: *FCS is included in the frame format to facilitate this service.*

3.2.2.4.1.3 Station Identification

The DLS sublayer shall only pass frames to the upper layers that are addressed to it.

Note: *Unique source and destination addresses are included in the frame format to facilitate this service.*

3.2.2.4.1.4 Broadcast Addressing

~~The~~ VDL Mode 2 shall support broadcast addressing.

3.2.2.4.1.5 Data Transfer

Data shall be transferred in the information fields of VDL INFO, UI, and XID frames, per ISO 7809. The link layer shall process the largest packet size, specified in Section 3.2.3 of this document, without segmenting. One and only one data link user packet shall be contained in an INFO or UI.

3.2.2.4.2 AVLC Data Link Service Protocol Specification

3.2.2.4.2.1 Frame Format

AVLC frames shall conform to ISO 3309 frame structure except as specified in Figure 3-4.

> *Note: A transmitter may include more than one frame in a single physical layer transmission, with a single flag separating each frame.*

3.2.2.4.2.2 Address Structure

The address field shall consist of eight octets. As described in ISO 3309, option 7, the least significant (first transmitted) bit of each octet shall be reserved for address extension. When set to binary 0 it shall indicate that the rest of the following octet is an extension of the address field. The presence of binary 1 in the first transmitted bit of the address octet shall indicate that the octet is the final octet of the address field.

		MSB			**Bit Number**				First Bit Transmitted ↓LSB
Description	**Octet No.**	8	7	6	5	4	3	2	1
Flag	0	0	1	1	1	1	1	1	0
Destination Address Field	1	d_{22}	d_{23}	d_{24}	d_{25}	d_{26}	d_{27}	A/G	0
	2	d_{15}	d_{16}	d_{16}	d_{18}	d_{19}	d_{20}	d_{21}	0
	3	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	0
	4	d_1	d_2	d_3	d_4	d_5	d_6	d_7	0
Source Address Field	5	s_{22}	s_{23}	s_{24}	s_{25}	s_{26}	s_{27}	C/R	0
	6	s_{15}	s_{16}	s_{17}	s_{15}	s_{19}	S_{20}	s_{21}	0
	7	s_8	s_9	s_{10}	s_{11}	s_{12}	s_{13}	s_{14}	0
	8	s_1	s_2	s_3	s_4	s_5	s_6	s_7	1
Link Control Field	9				P/F				
Information Field	N-2	USER DATA							
Frame Check Sequence	N-1	fcs_9	fcs_{10}	fcs_{11}	fcs_{12}	fcs_{13}	fcs_{14}	fcs_{15}	fcs_{16}
	N	fcs_1	fcs_2	fcs_3	fcs_4	fcs_5	fcs_6	fcs_7	fcs_8
Flag	N+1	0	1	1	1	1	1	1	0

Defined: A/G - Air/Ground bit
C/R - Command/Response bit
P/F - Poll/Final bit

Figure 3-4: Link Layer Frame Format

3.2.2.4.2.3 Address Fields

The address field shall contain a destination address field and a source address field. The destination address field shall contain a destination

DLS address or a broadcast address. The source address field shall contain a DLS address. There is a status bit in the source address and a status bit in the destination address field, which shall be set by the transmitting station to reflect status information. The status bits and address details are defined in Sections 3.2.2.4.2.3.1 to 3.2.2.4.2.3.7.

Note: *See the ICAO VDL Mode 2 SARPs Implementation Aspects for information on address fields.*

3.2.2.4.2.3.1 Air/Ground Status Bit

The status bit in the destination address field (bit 2, octet 1) shall be the Air/Ground (A/G) bit. The A/G bit shall be set to 0 to indicate that the transmitting station is airborne. It shall be set to 1 to indicate that the transmitting station, either fixed or mobile, is on the ground. The default value for the A/G bit shall be 0 for aircraft that do not provide this information at the link level; the value shall be 1 for ground stations.

3.2.2.4.2.3.2 Command/Response Status Bit

The status bit in the source address field (bit 2, octet 5) shall be the Command/Response (C/R) bit. The C/R bit shall be set to 0 to indicate a command frame, and set to 1 to indicate a response frame.

3.2.2.4.2.3.3 Data Link Service Addresses

The DLS address shall be 27 bits divided into a 3-bit type field and a 24-bit station specific address field.

3.2.2.4.2.3.4 Address Type

The address type field is described in Table 3-4.

Table 3-4: Address Type Field Encoding

Description Type	**Type Field**			**Station Specific Address Field**
	27	**26**	**25**	
Reserved	0	0	0	Future use
Aircraft	0	0	1	24-bit ICAO address
Reserved	0	1	0	Future use
Reserved	0	1	1	Future use
Ground Station	1	0	0	ICAO-administered address space
Ground Station	1	0	1	ICAO-delegated address space
Reserved	1	1	0	Future use

All stations broadcast	1	1	1	All stations

3.2.2.4.2.3.5 Aircraft Specific Addresses

The aircraft specific address field shall be the 24-bit ICAO aircraft address.

3.2.2.4.2.3.6 ICAO-Administered Ground Station Specific Addresses

The ICAO-administered ground station specific address shall consist of a variable-length country code prefix (using the same country codes assignment defined in ICAO Annex 10, Volume III, Chapter 9, Appendix 1, Table 1 to the convention) and a suffix. The appropriate authority shall assign the bits in the suffix.

3.2.2.4.2.3.7 ICAO-Delegated Ground Station Specific Addresses

The ICAO-delegated ground station specific address shall be determined by the organization to which the address space is delegated.

3.2.2.4.2.4 Broadcast Address

The broadcast address shall be used only as a destination address for unnumbered information (UI) frames or for XID frames broadcasting ground station information.

3.2.2.4.2.4.1 Encoding

The broadcast addresses shall be encoded as in Table 3-5.

Table 3-5: Broadcast Address Encoding

Broadcast Destination	**Type Field** **27 26 25**	**Station Specific Address Field**	
All aircraft	0 0 1	All ones	
All ground stations of a particular provider	1 0 0 or 1 0 1	Most significant bits	Remaining bits
		Variable length provider code	All ones
All ground stations with ICAO-administered addresses	1 0 0	All ones	

All ground stations	1 0 1	All ones
All stations	1 1 1	All ones

Note: "All ground stations" refers to the ground station with ICAO administered addresses and those of a particular provider and "All stations" refers to both "All aircraft" and "All ground stations".

3.2.2.4.2.5 Link Control Field

The basic repertoire of commands and responses for AVLC shall be as detailed in Table 3-6 and shall be encoded per ISO 4335.

3.2.2.4.2.6 Information Field

The information field of an SREJ shall be as defined in Section 3.2.2.4.10.2, an XID shall be as defined in Section 3.2.2.5.2, and all other frames shall be as defined in ISO 4335.

Table 3-6: AVLC Commands and Responses

Commands	Responses
INFO [Information]	INFO
RR [Receive Ready]	RR
XID [Exchange Identity]	XID
TEST	TEST
SREJ [Selective Reject]	SREJ [Selective Reject]
FRMR [Frame Reject]	
UI [Unnumbered INFO]	UA [Unnumbered Acknowledgment]
DISC [Disconnect]	DM [Disconnected mode]

3.2.2.4.3 Data Link Service System Parameters

These parameters needed by the DLS sublayer shall be as listed in Table 3-7 and detailed in Sections 3.2.2.4.3.1 through 3.2.2.4.3.7. DLS parameters shall be set using XID frames.

3.2.2.4.3.1 Timer T1 (Delay Before Retransmission)

The T1 timer shall be set to the time that a DLE will wait for an acknowledgment before retransmitting an INFO, RR (P=1), SREJ (P=1), or an FRMR frame.

The value of Timer T1 shall be computed by the following formula:

$$\text{Timer T1} = \text{T1min} + 2\text{TD}_{99} + \min(\text{U}(x),\text{T1max})$$

Where:

$$\text{TD}_{99} = (\text{TM1}*\text{M1})/(1-u)$$

and is the running estimate for the 99th percentile transmission delay (between the time at which the frame is sent to the MAC sublayer and the time at which its transmission is completed).

Table 3-7: Data Link Service System Parameters

Symbol	*Parameter Name*		*Lower Bound*	*Upper Bound*	*VDL Mode 2 Default*	*Increment*
T1min	*Delay before retransmission*	*Minimum*	*0 s*	*20 s*	*1.0 s*	*1 ms*
T1max		*Maximum*	*1 s*	*20 s*	*15 s*	*1 ms*
T1mult		*Multiplier*	*1*	*2.5*	*1.45*	*0.01*
T1exp		*Exponent*	*1*	*2.5*	*1.7*	*0.01*
T2	*Delay before ACK*		*25 ms*	*10 s*	*500 ms*	*1 ms*
T3min	*Link Initialization Time*	*Minimum*	*5 s*	*25 s*	*6 s*	*1 ms*
T3max		*Maximum*	*1 s*	*20 s*	*15 s*	*1 ms*
T3mult		*Multiplier*	*1*	*2.5*	*1.45*	*0.01*
T3exp		*Exponent*	*1*	*2.5*	*1.7*	*0.01*
T4	*Max delay between transmissions*	*aircraft*	*10 min*	*1440 min*	*20 min*	*1 min*
		ground	*12 min*	*1442 min*	*22 min*	*1 min*
N1	*Maximum number of bits in any frame*		*1144 bits*	*16504 bits*	*8312 bits*	*1 bit*
N2	*Maximum number of transmissions*		*1*	*15*	*6*	*1*
k	*Window Size*		*1 frame*	*7 frames*	*4 frames*	*1 frame*

u is a measurement of channel utilization with a range of value from 0 to 1, with 1 corresponding to a channel that is 100 percent occupied.

U(x) is a uniform random number generated between 0 and x.

x $= \text{T1mult* TD}_{99} \text{ *T1exp}^{\text{retrans}}$

retrans is the largest retransmission count of all of the outstanding frames.

Timer T1 shall be started after any INFO, RR (P=1), SREJ (P=1), or FRMR frame is queued for transmission unless it is already running. If the timer expires, all outstanding INFO, RR (P=1), SREJ (P=1), or FRMR frames that have been queued for at least T1min + 2TD shall be retransmitted. The timer shall be canceled upon receipt of an acknowledgment.

After processing an acknowledgment or Timer T1 expires, Timer T1 shall be restarted if there are still frames outstanding. Whenever the T1 timer is restarted, the timer shall be set as if it had been started when the oldest outstanding frame was queued.

Note: There is one Timer T1 per DLE.

3.2.2.4.3.2 Parameter T2 (Delay Before Acknowledgment)

Parameter T2 defines the maximum time allowed for the DLE to respond to any received frame (other than an XID) in order to ensure the response is received before the peer DLE's Timer T1 expires.

A DLE shall respond to any received frame (other than an XID) within parameter T2 time in order to ensure the response is received before the peer DLE's Timer T1 expires.

Note: The period T2 should be a delay (shorter than the T1min value of the peer DLE) to permit the acknowledging DLE to schedule the response as an event in normal data processing and to allow sufficient time for an acknowledgment while maximizing the likelihood that an INFO frame will be transmitted and eliminate the need for an explicit acknowledgment.

3.2.2.4.3.3 Timer T3 (Link Initialization Time)

Timer T3 shall be set to the time that a DLE waits for an XID response before retransmitting an exchange identification command (XID_CMD).

The period of the Timer T3 shall be computed by using the same algorithm and parameters as Timer T1, except that T3min shall be separately negotiated. XID_CMDs (except for ground station information frames) shall be retransmitted using the procedures defined in Section 3.2.2.4.3.1.

Notes:

1. *There is one Timer T3 per DLE.*
2. *T3min must be greater than T1min to allow the responding entity time to coordinate the response and perform any additional initialization processing.*

3.2.2.4.3.4 Timer T4 (Maximum Delay Between Transmissions)

Timer T4 shall be set to the maximum delay between transmissions (T4). Timer T4 shall be started or restarted on en-queuing a frame for transmission. Timer T4 shall never be canceled.

If a DLE does not receive a frame before Timer T4 expires, it shall send a command frame (P=1) to ensure a response from the peer DLE. When in the asynchronous balanced mode (ABM), the DLE shall send a receive ready frame (RR); when in the sent selective reject mode (SRM), the DLE shall send a selective reject frame (SREJ); when in the frame reject mode (FRM), the DLE shall send a frame reject frame (FRMR).

The value of Timer T4 shall be at least two minutes longer for a ground DLE than for the peer aircraft DLE. The command frame shall be transmitted using normal Timer T1 procedures up to N2 times. If no response is received, the DLE shall assume that the link is disconnected and that link recovery procedures shall be invoked.

Notes:

1. *Timer T4 is used to verify the continued existence of the link.*
2. *There is one Timer T4 per DLE.*
3. *A DLE in the ABM or SRM should send any outstanding frames with the P bit of the last INFO frame set to 1.*

3.2.2.4.3.5 Parameter N1 (Maximum Number of Bits of any Frame)

The parameter N1 defines the maximum number of bits in any frame (excluding flags and zero bits inserted for transparency) that a DLS shall accept.

3.2.2.4.3.6 Counter N2 (Maximum Number of Transmissions)

Counter N2 defines the maximum number of transmissions that the DLS shall attempt to transmit any outstanding XID_CMD frame. A Counter N2 shall be set to zero when a new frame is ready for transmission. Counter N2 shall be incremented after each transmission of the frame. The counter shall be cleared after its associated frame is acknowledged.

When Timer T1 expires, a DLE shall invoke the retransmission procedures of Section 3.2.2.4.3.1 up to N2 - 1 times.

When Timer T3 expires, a DLE shall invoke the retransmission procedures of Section 3.2.2.4.3.3 up to N2 - 1 times.

When Counter N2 reaches the maximum number of attempts (value of parameter N2) the LME shall be informed and the frame shall not be transmitted.

Notes:

1. *There is one Counter N2 per an unacknowledged frame.*

2. *The value of the ground N2 parameter may be different from the value of the airborne N2 parameter.*

3.2.2.4.3.7 Parameter k (Window Size)

Parameter k shall be set to the maximum number of outstanding sequentially numbered INFO frames that may be transmitted before an acknowledgment is required.

Note: *The value of the ground k parameter may be different from the value of the airborne k parameter.*

3.2.2.4.4 Description of Procedures

Except as noted in Sections 3.2.2.4.5 through 3.2.2.4.10, the standard procedures described in ISO 4335 and ISO 7809 shall be followed.

3.2.2.4.5 Modes of Operation

The only modes of operation that a DLE shall support are detailed below.

3.2.2.4.5.1 Operational Mode

The operational mode shall be Asynchronous Balanced Mode (ABM).

3.2.2.4.5.2 Non-operational Mode

The non-operational mode shall be Asynchronous Disconnected Mode (ADM).

> Note: *Among the reasons a DLE or LME enters the non-operational mode include issuing or receiving any of the following frames: DISC, XID_CMD_LCR, DM, or XID_RSP_LCR. Abbreviated frame names are defined in Tables 3-6 and 3-14.*

3.2.2.4.5.2.1 DISC Frame

If a DLE is unable to continue to receive, it shall transmit a DISC to terminate the current link. The P bit shall be set to 0 in DISC commands. A DLE shall treat all received DISCs (regardless of the P bit) as a DISC (P=0).

> Note: *The use of a DISC command may result in the loss of unacknowledged data.*

3.2.2.4.5.2.2 DM Frame

If a DLS receives any valid unicast frame, except for an XID or TEST frame, from a DLS with which it does not have a link, it shall respond with a DM frame. All DM frames shall be transmitted with the F bit set to 0.

An aircraft transmitting or receiving a DM frame shall initiate link establishment on one LME if no links remain. A DLE shall treat all received DMs (regardless of the F bit) as a DM (F=0).

> Notes:
>
> 1. *If an LME is in the process of executing a handoff, it will retransmit the XID_CMD_HO (P=1) and wait for the Timer T3 to expire.*
> 2. *A station receiving an invalid frame may choose to discard the frame instead of responding with a DM.*
> 3. *The procedures for an LME receiving a unicast XID from an LME with which it does not have a link are found in Section 3.2.2.5.4.*

3.2.2.4.5.2.3 Frame Reject Mode

When in ABM or SRM, and after transmitting an FRMR command, the DLE shall enter the frame reject mode (FRM). The DLE shall reenter the ABM only after it receives a UA (F=1) frame.

3.2.2.4.5.2.4 Sent Selective Reject Mode

When in ABM, and after transmitting an SREJ, the DLE shall enter the sent selective reject mode (SRM). The DLE shall re-enter the ABM only after it receives the missing INFO frames.

3.2.2.4.6 Use of the P/F Bit

The use of the P/F bit shall follow the procedures detailed in ISO 4335, except as modified by Sections 3.2.2.4.6.1 through 3.2.2.4.6.3.

3.2.2.4.6.1 General

When a DLE receives a command frame with the P bit set to 1, the F bit shall be set to 1 in the corresponding response frame. The C/R bit in the address field shall be referenced to resolve the ambiguity between command and response frames.

3.2.2.4.6.2 INFO Frames

After receiving an INFO frame, a DLE shall generate an acknowledgment, within T2 seconds after detecting the end of transmission. If a valid INFO (P=1) is received, the response shall be either an RR (F=1) or SREJ (F=1). If a valid INFO (P=0) is received, the response shall be either an RR (F=0) or SREJ (F=0).

> Note: *The only time an RR or an SREJ frame should be transmitted with P = 1 is when T4 expires. The only time that an INFO frame should be transmitted with P=1 is either when T4 expires or the transmit window has closed.*

3.2.2.4.6.3 Unnumbered Frames

The P bit shall be set to 0 for UI and DISC frames. The F Bit shall be set to 0 for DM frames. Therefore, a response (e.g., UA) shall not be expected, and if received, shall be treated as an error.

3.2.2.4.7 Unnumbered Command Frame Collisions

When a command frame collision occurs, the entity that has precedence shall discard the received frame from its peer entity and the peer entity shall respond as if it had never sent its command frame.

3.2.2.4.7.1 DLE Procedures

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While waiting for a response to an unnumbered command frame (i.e., FRMR), a DLE whose DLS address is lower than its peer DLE shall have precedence.

3.2.2.4.7.2 LME Procedures

An LME receiving a Broadcast Handoff shall process it before responding to any XID_CMD. An LME sending an XID_CMD (P=1) shall have precedence over an LME sending an XID_CMD (P=0). Otherwise, an LME whose DLS address is lower than its peer LME shall have precedence.

3.2.2.4.8 XID Frame

The XID frame shall be used for the LME to establish and maintain a link as defined in Section 3.2.2.5. The originator of an XID_CMD (P = 1) frame shall retransmit the XID upon expiration of the Timer T3 whenever no response has been received. The receiving LME shall use the XID sequence number and retransmission field to differentiate a retransmission from a new XID; however, no meaning shall be attached to a missing sequence number. An LME shall send the exact same XID_RSP to every retransmission of an XID_CMD, unless it intends to change the link status via an XID_CMD (_HO, OR _LCR).

3.2.2.4.9 Broadcast

Only XID_CMDs or UIs shall be broadcast. The P/F bit shall be set to 0 (no acknowledgment) for broadcast frames.

3.2.2.4.10 Information Transfer

Except as noted below, the procedures for information transfer shall be specified by ISO 4335 and ISO 7809.

3.2.2.4.10.1 Transmission Queue Management

When the DLS sublayer has frames to transmit, it shall wait for the MAC sublayer to authorize transmission. Two transmit queues shall be maintained, one for supervisory and unnumbered (XID, FRMR, TEST, DISC, DM, RR, SREJ) frames and the other for information frames (INFO and UI). While waiting for authorization to transmit, the DLS sublayer shall update the transmit queue, eliminating certain frames as specified in Sections 3.2.2.4.10.1.1 through 3.2.2.4.10.1.2. If all of the frames on the DLS transmit queue are eliminated, then the authorization to transmit shall be ignored.

3.2.2.4.10.1.1 Eliminate Redundant Frames

At most, one RR, SREJ, DM, FRMR, or retransmitted INFO (of a given sequence number) shall be queued in response to a transmission.

Notes:

1. *To eliminate redundant frames, superseded frames in the transmit queue should be deleted (e.g., an INFO frame queued in response to a T1 timeout and then an SREJ).*

2. *If any INFO frame is received from the peer DLE, the DLS sublayer should update the N(r) of all numbered frames addressed to that DLE in the transmit queue, thus improving the probability of the acknowledgment arriving.*

3. *To eliminate unnecessary retransmission, if any numbered frame is received from the peer DLE, all frames in the transmit queue that it acknowledges should be deleted. If an XID_CMD from a peer LME with a lower-DLS address or an XID_RSP is received from a peer LME, any XID_CMDs in the transmit queue for that LME should be deleted.*

3.2.2.4.10.1.2 Procedures for Transmission

Supervisory frames have higher priority than the information frames, so supervisory and unnumbered (XID, FRMR, TEST, DISC, DM) frames shall be transmitted in preference to information frames.

Notes:

1. *On transmission of an INFO frame, the DLE should piggyback any queued RR so as to avoid transmitting the RR as a separate frame.*

2. *A station receiving an FRMR, DISC, or DM frame should delete all outstanding traffic for the transmitting DLE as it would not be accepted if transmitted.*

3. *All unicast frames in the transmit queue should be deleted after the radio supporting this transmit queue is retuned as the intended station cannot receive the transmission.*

3.2.2.4.10.2 SREJ Frame

The multi-selective reject option in ISO 4335 shall be used to request the retransmission of more than one INFO frame. The SREJ (F=0) frame shall be generated only after receipt of an out-of-order INFO (P=0) frame. The SREJ (F=1) shall be generated only after receipt of an INFO

(P=1), RR (P=1) or SREJ (P=1). The SREJ (P=1) frame shall be generated only in accordance with the procedures of Section 3.2.2.4.3.4. A DLE shall acknowledge those frames which were received correctly but out of order by including in the SREJ information field an octet with bits 6-8 set to the INFO frame's sequence number and bit 1 set to 1. Although the F bit may be set to 0, the SREJ frame shall always acknowledge INFO frames up to N(r)-1 (where N(r) is the value in the control field).

> Note: *AVLC has extended the standard ISO 4335 SREJ functionality to selectively acknowledge frames. In ISO 4335, the octets in the information field which were requesting retransmission of frames had bit position 1 set by default to 0.*

3.2.2.4.10.3 FRMR Frame

If a DLE receives an illegal frame (as defined by ISO 4335), it shall transmit an FRMR (P=1) to reset the link (e.g., state variables, timers and queues). A DLE, on receiving or transmitting a UA (F=1), shall reset the link (no XID exchange required). A DLE shall use the normal T1 and N2 procedures during the FRMR/UA exchange. A DLE transmitting the FRMR shall also retransmit the FRMR either upon expiration of Timer T4 or upon receipt of any frame other than a UA (F=1). A DLE receiving an illegal FRMR shall either discard the frame or treat it as a valid FRMR.

3.2.2.4.10.4 UA Frame

The UA frame shall be used only to acknowledge an FRMR.

3.2.2.4.10.5 UI Frame

UI frames shall be used solely to support connectionless data transfer required to provide broadcast services.

3.2.2.4.10.6 TEST Frame

> Note: *The TEST command/response exchange has been included in AVLC to allow a station to perform a loopback test using logic that is isolated from the normal frame processing.*

3.2.2.5 VDL Management Entity

3.2.2.5.1 Services

The services of the VME shall be link provision and link change notifications.

3.2.2.5.1.1 Link Provision

A VME shall have an LME for each peer LME. Hence, a ground VME shall have an LME per aircraft and an aircraft VME shall have an LME per ground system. An LME shall establish a link between a local DLE and a remote DLE associated with its peer LME. A ground LME shall determine if an aircraft station is associated with its peer aircraft LME by comparing the aircraft address; two aircraft stations with identical aircraft addresses are associated with the same LME. An aircraft LME shall determine if a ground station is associated with its peer ground LME by bit-wise logical ANDing the DLS address with the station ground system mask provided by the peer ground LME; two ground stations with identical masked DLS addresses are associated with the same LME.

Each aircraft and ground LME shall monitor all transmissions from its peer's station(s) to maintain a reliable link between some ground station and the aircraft while the aircraft is in coverage of a ground station.

> Note: *If an aircraft receives a frame from a ground station, one and only one LME will process and react to that frame. Thus the qualifying phrase "from a ground station associated with its peer LME" will not be included and should be understood to be implied.*

3.2.2.5.1.2 Link Change Notifications

The VME shall notify the intermediate-system system management entity (IS-SME) of changes in link connectivity by supplying information contained in the XID frames received.

3.2.2.5.2 Exchange Identity (XID) Parameter Formats

In the tables included in the subsections to this section, the following order is implied:

a. Bit order in each parameter value shall be indicated by subscript numbers. Bit 1 shall indicate the least significant bit.
b. Bits shall be transmitted octet by octet, starting with the parameter ID, and within each octet the right most bit (as shown in the tables) shall be transmitted first.

Notes:

1. *The tables are divided into three major columns that define the field name, the bit encoding and brief explanatory notes.*

2. *Requirements for the use of the parameters defined in the following sections are defined in Section 3.2.2.5.4.*

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3.2.2.5.2.1 Encoding

The XID information field shall be encoded per ISO 8885 and may include the parameters described in Sections 3.2.2.5.2.2 or 3.2.2.5.2.7.

3.2.2.5.2.2 Public Parameters

XID parameters shall be encoded as defined in ISO 8885, with the addition of the private parameter data link layer subfield as defined in ISO 8885. The format identifier (hexadecimal 82) shall be used (per ISO 4335.2, Annex C) to identify the public parameter list identified in ISO 8885. The VDL shall use the public parameter group ID of hexadecimal 80 to negotiate the common HDLC parameters. The public parameter set ID shall be included in XID frames if other public parameters are included; the public parameter set ID shall not be included in XID frames if other public parameters are not included.

> Note: *ISO 8885 defines certain public parameters as receive and transmit which are referred to herein as uplink and downlink respectively.*

3.2.2.5.2.2.1 HDLC Public Parameter Set Identifier

The HDLC parameter set shall be identified by the ISO IA5 character string "8885:1993" encoded as per Table 3-8. This parameter shall be included whenever any of the public parameters are sent. It shall be the first public parameter sent per ISO 8885.

Table 3-8: HDLC Public Parameter Set Identifier

Parameter ID	0	0	0	0	0	0	0	1	
Parameter length	0	0	0	0	1	0	0	1	
Parameter value	0	0	1	1	1	0	0	0	character '8'
	0	0	1	1	1	0	0	0	character '8'
	0	0	1	1	1	0	0	0	character '8'
	0	0	1	1	0	1	0	1	character '5'
	0	0	1	1	1	0	1	0	character ':'
	0	0	1	1	0	0	0	1	character '1'
	0	0	1	1	1	0	0	1	character '9'
	0	0	1	1	1	0	0	1	character '9'
	0	0	1	1	0	0	1	1	character '3'

3.2.2.5.2.2.2 Timer T1

This parameter defines the value of the downlink Timer T1 that an aircraft DLE shall use. The values shall be defined in units of milliseconds for T1min and T1max and in hundredths for T1mult and T1exp. The timer values shall be encoded as 4 unsigned 16-bit integers per Table 3-9:

Note: Refer to Table 3-7 for more information on Timer T1 parameters.

3.2.2.5.2.3 VDL Private Parameters

The parameter identifier fields shall allow simple identification of the purpose of the parameter as defined in Table 3-10:

3.2.2.5.2.4 General Purpose Information Private Parameters

Both aircraft and ground LMEs shall use general purpose information private parameters to transfer basic information to each other.

Note: ISO 8885 defines the group identifier of the private parameter function to be the hexadecimal value F0.

Table 3-9: Timer T1 Parameter

Parameter ID	0	0	0	0	1	0	0	1	
Parameter length	0	0	0	0	1	0	0	0	
Parameter value	l_{16}	l_{15}	l_{14}	l_{13}	l_{12}	l_{11}	l_{10}	l_9	(T1min)
	l_8	l_7	l_6	l_5	l_4	l_3	l_2	l_1	
	u_{16}	u_{15}	u_{14}	u_{13}	u_{12}	u_{11}	u_{10}	u_9	(T1max)
	u_8	u_7	u_6	u_5	u_4	u_3	u_2	u_1	
	m_{16}	m_{15}	m_{14}	m_{13}	m_{12}	m_{11}	m_{10}	m_9	(T1mult)
	m_8	m_7	m_6	m_5	m_4	m_3	m_2	m_1	
	e_{16}	e_{15}	e_{14}	e_{13}	e_{12}	e_{11}	e_{10}	e_9	(T1exp)
	e_8	e_7	e_6	e_5	e_4	e_3	e_2	e_1	

Table 3-10: VDL Private Parameter Identification

Bit 8	Bit 7	Purpose

0	0	General purpose information private parameter
0	1	Ground-initiated modification private parameter
1	0	Aircraft-initiated information private parameter
1	1	Ground-initiated information private parameter

3.2.2.5.2.4.1 VDL Private Parameter Set Identifier

The VDL Private Parameter set identifier shall be by the ISO IA5 character capital 'V' encoded per Table 3-11. This parameter shall be included whenever any of the private parameters are to be sent. It shall be the first private parameter sent per ISO 8885.

Table 3-11: Private Parameter Set Identification

Parameter ID	0	0	0	0	0	0	0	0	
Parameter length	0	0	0	0	0	0	0	1	
Parameter value	0	1	0	1	0	1	1	0	Character V

3.2.2.5.2.4.2 Connection Management Parameter

This parameter defines the type of XID sent and the connection options negotiated for that particular link. It shall be used in XID frames sent during link establishment and ground initiated ground station handoff per Tables 3-12, 3-13, and 3-14. An LME shall set the reserved bits to 0 on transmission, and shall ignore the value of these bits on receipt.

Table 3-12: Connection Management Parameter

Parameter ID	0	0	0	0	0	0	0	1
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1
Parameter value	0	0	0	0	v	x	r	h

Note: The value in the parameter length field is variable to allow for the possibility of additional options.

Table 3-13: Connection Management Parameter Values

Bit	Name	Encoding	
1	h	h = 0	No link currently established.
		h = 1	Link currently established.
2	r	r = 0	Link connection accepted.
		r = 1	Link connection refused.
3	x	x = 0	Only VDL-specific ground DTE addresses.
		x = 1	Ground network DTE addresses accepted.
4	v	v = 0	Expedited subnetwork connection not supported
		v = 1	Expedited subnetwork connection supported.
5-8	Reserved	Set to 0	

Table 3-14: Abbreviated XID Names

Name	C/R	P/F	h	r	x	v	Notes
GSIF	0	0	-	-	-	-	Ground Station Identification Frame
XID_CMD_LE	0	1	0	0	x	x	Link Establishment
XID_CMD_LCR	0	0	0	1	x	x	Link Connection Refused
XID_CMD_LPM	0	1	-	-	-	-	Link Parameter Modification
XID_CMD_HO	0	1	1	0	x	x	If P=1, then initiating handoff.
XID_CMD_HO	0	0	1	0	x	x	If broadcast and P=0, then commanding a Broadcast Handoff. If unicast and P=0, then Requesting Handoff.
XID_RSP_LE	1	1	0	0	x	x	
XID_RSP_LCR	1	1	0	1	x	x	
XID_RSP_LPM	1	1	-	-	-	-	
XID_RSP_HO	1	1	1	0	x	x	

x = don't care case

- = connection management parameter not included

3.2.2.5.2.4.3 Signal Quality Parameter (SQP)

This parameter defines the received signal quality value of the last received transmission from the destination of the XID. It shall be encoded as a 4-bit integer per Table 3-15:

Table 3-15: Signal Quality Parameter

Parameter ID	0	0	0	0	0	0	1	0
Parameter length	0	0	0	0	0	0	0	1
Parameter value	0	0	0	0	q_4	q_3	q_2	q_1

The contents of the SQP value field (q bits) are as defined in Section 3.2.1.1.4.

If the transmitting LME included the SQP parameter in the XID_CMD (P=1) frame, then the responding LME shall also include it in the respective XID_RSP (F=1) frame.

Note: This parameter will be used for testing purposes.

3.2.2.5.2.4.4 XID Sequencing Parameter

This parameter defines the XID sequence number (s s s) and an XID retransmission number (r r r r). It shall be encoded per Table 3-16. An LME shall increment the sequence number for every new XID (setting the retransmission field to 0 on the first transmission) and shall increment the retransmission field after every retransmission. In an XID_RSP, the sequence number shall be set to the value of the XID_CMD sequence number generating the response (the retransmission field shall be ignored).

Table 3-16: XID Sequence Parameter

Parameter ID	0	0	0	0	0	0	1	1
Parameter length	0	0	0	0	0	0	0	1
Parameter value	r_4	r_3	r_2	r_1	0	s_3	s_2	s_1

3.2.2.5.2.4.5 AVLC Specific Options Parameter

This parameter defines which AVLC protocol options are supported by the transmitting station. It shall be encoded per Tables 3-17 and 3-18. An LME shall set the reserved bits to 0 on transmission, and shall ignore the value of these bits on receipt. When both this parameter and the Connection Management parameter are included in an XID, the bit values for those options which are included in both parameters shall be determined by the Connection Management parameter.

Table 3-17: AVLC Specific Options Parameter Format

Parameter ID	0	0	0	0	0	0	0	0
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1
Parameter value	0	0	a	b_s	b_l	i	v	x

Notes:

1. *The value in the parameter length field is variable to allow for the possibility of additional options.*

2. *AVLC Specific Options Parameter Values are defined in Table 3-18.*

Table 3-18: AVLC Specific Options Parameter Values

BIT	Name	Value	Description
1	x	x = 1	Only VDL-specific DTE addresses
		x = 0	Ground network DTE address accepted
2	v	v = 0	Expedited subnetwork connection not supported
		v = 1	Expedited subnetwork connection is supported
3	i	i = 0	Does not support initiated handoff
		i = 1	Supports initiated handoff
4	b_l	$b_l = 0$	Broadcast link handoff not supported
		$b_l = 1$	Broadcast link handoff supported
5	b_s	$b_s = 0$	Broadcast subnetwork connection not supported
		$b_s = 1$	Broadcast subnetwork connection supported
6	a	a = 0	ATN service supported and/or requested
		a = 1	ACARS over AVLC service supported and/or requested
7	Reserved	Set to 0	Reserved for future use
8	Reserved	Set to 0	Reserved for future use

Notes:

1. *The AVLC Specific Options parameter (a) received from the aircraft is interpreted as:*

a = 0 ATN Service Requested
a = 1 AOA Service Requested

The AVLC Specific Options parameter (a) received from the ground is interpreted as:

a = 0 ATN Service Available, AOA service not available
a = 1 AOA and ATN Services Available

2. *If the ground system sends a GSIF with the (a = 1) in the AVLC specific options and the VSDA of the Ground system is 0, then the system is only capable of providing AOA services. This feature is designed to accommodate the transition period, without reserving additional bits.*

3.2.2.5.2.4.6 Expedited Subnetwork Connection Parameter

This parameter defines the expedited packets that the current XID contains. This parameter, which may be repeated, shall contain one and only one of the following subnetwork packets: CALL REQUEST, CALL CONFIRMATION, or a CLEAR REQUEST. It shall be encoded per Table 3-19. The inclusion of this parameter shall invoke the expedited subnetwork connection procedures. If, during link establishment, an aircraft LME has not received a ground station information frame (GSIF) from the ground LME, it may assume expedited subnetwork connection is supported.

Table 3-19: Expedited Subnetwork Connection

Parameter ID	0	0	0	0	0	1	0	1	
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	
Parameter value	p_8	p_7	p_6	p_5	p_4	p_3	p_2	p_1	an ISO 8208 octet

Note: *The value in the parameter length field is variable to allow for the possibility of additional options.*

3.2.2.5.2.4.7 LCR Cause Parameter

This parameter defines the reason why the link connection request was refused. The parameter, which may be repeated, shall consist of a rejection cause code (c bits), backoff delay time in seconds (d bits), and any additional data required by the various parameters. It is encoded per Table 3-20. Cause codes 00 hex to 7F hex shall apply to the responding station; cause codes 80 hex to FF hex shall apply to the responding system and shall be encoded per Table 3-21.

At least one copy of this parameter shall be included whenever the r bit in the Connection Management parameter is set to 1; this parameter shall not be included if the r bit is set to 0. An LME receiving an LCR Cause parameter less than 80 hex shall not transmit another XID_CMD to that peer station for the duration of time designated in the LCR Cause parameter. An LME receiving an LCR Cause parameter greater than 7F hex shall not transmit another XID_CMD to that peer system for the duration of time designated in the LCR Cause parameter.

Note: *An aircraft LME receiving a station-based cause code from one ground station may immediately transmit the same XID_CMD to another ground station of the same ground system.*

Table 3-20: LCR Cause Parameter

Parameter ID	0	0	0	0	0	1	1	0	
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	
Parameter value	c_8	c_7	c_6	c_5	c_4	c_3	c_2	c_1	cause
	d_{16}	d_{15}	d_{14}	d_{13}	d_{12}	d_{11}	d_{10}	d_9	delay
	d_8	d_7	d_6	d_5	d_4	d_3	d_2	d_1	
	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	additional data

Note: *The value in the parameter length field is variable to allow for the possibility of additional options.*

Table 3-21: Cause Code Table

Cause	Function	Additional Data Encoding
00h	Bad local parameter. The additional data block, which may be repeated, contains the GI and PI of a parameter which cannot be satisfied by this ground station. This cause will not be sent for an illegal Connection Management parameter.	g8 g7 g6 g5 g4 g3 g2 g1 p8 p7 p6 p5 p4 p3 p2 p1
01h	Out of link layer resources.	undefined
02h	Out of packet layer resources.	
03h	Terrestrial network not available.	
04h	Terrestrial network congestion.	
05h	Cannot support autotune.	
06h	Station cannot support initiating handoff.	
07-7Eh	Reserved	
7Fh	Other unspecified local reason.	
80h	Bad global parameter. The additional data block, which may be repeated, contains the GI and PI of a parameter which cannot be satisfied by any ground station in the system. This cause will not be sent for an illegal Connection Management parameter.	identical to cause code 00
81h	Protocol Violation. The first octet of the additional data block contains: 1- C/R bit (c bit) of the received XID; 2- P/F bit (p bit) of the received XID; 3- Disconnected bit (d bit) shall be set to 1 if the LME has no links with the remote LME (the unexpected bit shall also be set to 1); 4- Illegal bit (i bit) shall be set to 1 if the LME receives an illegal XID (i.e., not listed in Table 3-50 and described in Section 3.2.2.5.4); 5- Unexpected bit (u bit) shall be set to 1 if the LME receives a legal XID which is not legal in the context in which it was received. The remaining octets contains the parameter value of the Connection Management parameter (m bits) if included in the illegal XID. After transmitting or receiving an LCR with this cause code, an LME shall delete all of its links.	0 0 0 u i d p c m8 m7 m6 m5 m4 m3 m2 m1
82h	Ground system out of resources.	
83-FEh	Reserved	
FFh	Other unspecified system reason.	

Note: See G1 and P1 definitions in the key below Table 3-48c.

3.2.2.5.2.5 Aircraft-Initiated Information Private Parameters

An aircraft LME shall use aircraft-initiated information parameters to inform the ground about that aircraft's capabilities or desires. Ground LMEs shall not send these parameters.

3.2.2.5.2.5.1 Modulation Support Parameter

This parameter shall indicate the modulation schemes supported. This parameter shall be sent on link establishment. Encoding shall be as shown in Tables 3-22 and 3-23:

Table 3-22: Modulation Support

Parameter ID	1	0	0	0	0	0	0	1
Parameter length	0	0	0	0	0	0	0	1
Parameter value	0	0	0	0	m_4	m_3	m_2	m_1

Table 3-23: Modulation Scheme and Bit Rate

Bit	Name	Encoding	
1	Reserved	Set to 0	
2	D8PSK	0	(Not Mode 2)
		1	Mode 2, 31 500 bits/s
3	D8PSK	0	(Not Mode 3)
		1	Mode 3, 31 500 bits/s
4	Reserved	Set to 0	
Note: More than one modulation scheme may be supported by an aircraft.			

3.2.2.5.2.5.2 Acceptable Alternate Ground Station Parameter

This parameter defines a list of ground stations in order of preference. This parameter shall be a list of DLS addresses encoded in 32-bit fields as per Table 3-24. These shall be used by the ground LME during handoffs as possible alternate ground stations, if the proposed ground station is not acceptable to the ground LME.

Table 3-24: Acceptable Alternative Ground Station Parameter

Parameter ID	1	0	0	0	0	0	1	0	
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	
Parameter value	g_{22}	g_{23}	g_{24}	g_{25}	g_{26}	g_{27}	0	0	DLS address
	g_{15}	g_{16}	g_{17}	g_{18}	g_{19}	g_{20}	g_{21}	0	
	g_8	g_9	g_{10}	g_{11}	g_{12}	g_{13}	g_{14}	0	
	g_1	g_2	g_3	g_4	g_5	g_6	g_7	0	

3.2.2.5.2.5.3 Destination Airport Parameter

This parameter defines the aircraft's destination airport identifier. It shall be encoded as four 8-bit ISO IA5 characters per Table 3-25:

Table 3-25: Destination Airport

Parameter ID	1	0	0	0	0	0	1	1	
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	
Parameter value	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	first character
	b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1	
	c_8	c_7	c_6	c_5	c_4	c_3	c_2	c_1	
	d_8	d_7	d_6	d_5	d_4	d_3	d_2	d_1	fourth character

3.2.2.5.2.5.4 Aircraft Location Parameter

This parameter defines the current position of the aircraft. It shall be encoded as shown in Tables 3-26 and 3-27.

Table 3-26: Aircraft Location

Parameter ID	1	0	0	0	0	1	0	0	
Parameter length	0	0	0	0	0	1	0	0	
Parameter value	v_{12}	v_{11}	v_{10}	v_9	v_8	v_7	v_6	v_5	Latitude (v)
	v_4	v_3	v_2	v_1	h_{12}	h_{11}	h_{10}	h_9	
	h_8	h_7	h_6	h_5	h_4	h_3	h_2	h_1	Longitude (h)
	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	Altitude (a)

Table 3-27: Aircraft Location Subfield Description

Subfield	Range	Encoding	Notes	Abbreviation
Latitude	+ 90 to -90	Integer [degrees*10]	positive = north, negative = south, coded as two's complement	v bits
Longitude	+180 to - 180	Integer [degrees*10]	positive = east, negative = west, coded as two's complement	h bits
Altitude	0 to 255	Integer [FL / 10]	use 0 for< 999 feet, 255 for>= 255000 feet	a bits

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> *Note: For example, 100 degrees 18 minutes west equals 100.3 degrees west, which is expressed as -1003, the two's complement of which is encoded as C15 hexadecimal.*

3.2.2.5.2.6 Ground-Initiated Modification Private Parameters

A ground LME shall use the ground-initiated modification parameters to change the value of various parameters in one or more aircraft. Aircraft LMEs shall not send an XID with these parameters.

3.2.2.5.2.6.1 Autotune Frequency Parameter

This parameter defines the frequency and modulation scheme that an aircraft LME shall use to reply to a ground station listed in the replacement ground station parameter. This parameter shall be sent by a ground LME when an autotune is required. The parameter shall be encoded as a 16-bit field per Table 3-28. The modulation subfield (m bits) shall be defined per Table 3-23. The frequency subfield (f bits) shall be the frequency encoded as:

Integer [(frequency in MHz * 100) - 10000].

> *Note: As an example, for a frequency of 131.725 MHz, the encoded value is decimal 3172 or hexadecimal C64.*

Table 3-28: Autotune Frequency Parameter

Parameter ID	0	1	0	0	0	0	0	0
Parameter length	0	0	0	0	0	0	1	0
Parameter value	m_4	m_3	m_2	m_1	f_{12}	f_{11}	f_{10}	f_9
	f_8	f_7	f_6	f_5	f_4	f_3	f_2	f_1

3.2.2.5.2.6.2 Replacement Ground Station List

This parameter defines a list of ground stations in order of ground LME preference. This parameter shall be encoded as a list of DLS addresses in 32-bit fields per Table 3-29. These addresses shall be used by the aircraft LME during handoffs as possible alternate ground stations if the proposed ground station is not acceptable to the LME.

Table 3-29: Replacement Ground Station List

Parameter ID	0	1	0	0	0	0	0	1
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1
Parameter value	g_{22}	g_{23}	g_{24}	g_{25}	g_{26}	g_{27}	0	0
	g_{15}	g_{16}	g_{17}	g_{18}	g_{19}	g_{20}	g_{21}	0
	g_8	g_9	g_{10}	g_{11}	g_{12}	g_{13}	g_{14}	0
	g_1	g_2	g_3	g_4	g_5	g_6	g_7	0

3.2.2.5.2.6.3 Timer T4 Parameter

This parameter defines the value of the Timer T4 (in minutes) that the aircraft DLEs shall use. It shall be encoded as an unsigned 16-bit integer per Table 3-30:

Table 3-30: Timer T4 Parameter

Parameter ID	0	1	0	0	0	0	1	0
Parameter length	0	0	0	0	0	0	1	0
Parameter value	n_{16}	n_{15}	n_{14}	n_{13}	n_{12}	n_{11}	n_{10}	n_9
	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1

3.2.2.5.2.6.4 MAC Persistence Parameter

This parameter defines the value of the parameter p in the p-persistent CSMA algorithm that an aircraft MAC shall use. This 8-bit integer shall be encoded as Hexadecimal 00 (= Decimal 1/256) to Hexadecimal FF (= Decimal 1) per Table 3-31.

Table 3-31: MAC Persistence Parameter

Parameter ID	0	1	0	0	0	0	1	1
Parameter length	0	0	0	0	0	0	0	1
Parameter value	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1

3.2.2.5.2.6.5 Counter M1 Parameter

This parameter defines the value of M1 that an aircraft MAC shall use. It shall be encoded as a 16-bit unsigned integer per Table 3-32.

Table 3-32: Counter M1 Parameter

Parameter ID	0	1	0	0	0	1	0	0
Parameter length	0	0	0	0	0	0	1	0
Parameter value	n_{16}	n_{15}	n_{14}	n_{13}	n_{12}	n_{11}	n_{10}	n_9
	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1

3.2.2.5.2.6.6 Timer TM2 Parameter

This parameter defines the value of the Timer TM2 (in seconds) that an aircraft MAC shall use. It shall be encoded as an 8-bit integer per Table 3-33.

Table 3-33: Timer TM2 Parameter

Parameter ID	0	1	0	0	0	1	0	1
Parameter length	0	0	0	0	0	0	0	1
Parameter value	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1

3.2.2.5.2.6.7 Timer TG5 Parameter

This parameter defines the value of the Timer TG5 (in seconds) that the initiating and responding LME shall use. It shall be encoded as two 8-bit integers per Table 3-34.

Table 3-34: Timer TG5 Parameter

Parameter ID	0	1	0	0	0	1	1	0	
Parameter length	0	0	0	0	0	0	1	0	
Parameter value	i_8	i_7	i_6	i_5	i_4	i_3	i_2	i_1	initiating
	r_8	r_7	r_6	r_5	r_4	r_3	r_2	r_1	responding

3.2.2.5.2.6.8 T3min Parameter

This parameter defines the value of the T3min (in milliseconds) that the aircraft DLE shall use. It shall be encoded as an unsigned 16 bit integer per Table 3-35.

Table 3-35: T3min Parameter

Parameter ID	0	1	0	0	0	1	1	1
Parameter length	0	0	0	0	0	0	1	0
Parameter value	n_{16}	n_{15}	n_{14}	n_{13}	n_{12}	n_{11}	n_{10}	n_9
	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1

3.2.2.5.2.6.9 Ground Station Address Filter Parameter

This parameter defines the DLS address of the ground station from which links are handed off. This parameter shall be sent in an XID_CMD and a receiving aircraft LME shall process the XID_CMD only if it has a link to the identified ground station. The ground station address filter shall be encoded in a 32-bit field per Table 3-36.

Table 3-36: Ground Station Address Filter Parameter

Parameter ID	0	1	0	0	1	0	0	0
Parameter length	0	0	0	0	0	1	0	0
Parameter value	g_{22}	g_{23}	g_{24}	g_{25}	g_{26}	g_{27}	0	0
	g_{15}	g_{16}	g_{17}	g_{18}	g_{19}	g_{20}	g_{21}	0
	g_8	g_9	g_{10}	g_{11}	g_{12}	g_{13}	g_{14}	0
	g_1	g_2	g_3	g_4	g_5	g_6	g_7	0

3.2.2.5.2.6.10 Broadcast Connection Parameter

This parameter defines a single aircraft's link attributes for a new link, i.e.:

- aircraft address whose link was successfully established on the new link (minimum information);
- an optional list of one or more subnetwork connections maintained for that aircraft; and

- for each subnetwork connection listed, an indication of whether its subnetwork dependent convergence facility (SNDCF) context was maintained.

Per Table 3-37 and 3-38:

- the aircraft ID subfield (a bits) shall be listed once and shall be the aircraft address;
- the optional M/I subfield (m bit) shall be the SNDCF M/I bit in the CALL CONFIRMATION Call User Data field; and
- the optional LCI subfield (l bits) shall be the logical channel identifier of a subnetwork connection on the old link which is to be maintained on the new link.

Any particular aircraft shall not appear in more than one broadcast parameter block.

Note 1: Refer to Section 3.2.2.5.4.10.2 for more discussion of the M/I and LCI subfields.

Table 3-37: Broadcast Connection (Link Only) Parameter

Parameter ID	0	1	0	0	1	0	0	1	
Parameter length	0	0	0	0	0	0	1	1	
Parameter value	a_{24}	a_{23}	a_{22}	a_{21}	a_{20}	a_{19}	a_{18}	a_{17}	Aircraft ID
	a_{16}	a_{15}	a_{14}	a_{13}	a_{12}	a_{11}	a_{10}	a_9	
	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	

Note 2: Table 3-37 shows the case of a successful link handoff, with no switched virtual circuits (SVCs) maintained.

Table 3-38: Broadcast Connection (Link and Subnetwork) Parameter

Parameter ID	0	1	0	0	1	0	0	1	
Parameter length	0	0	0	0	0	1	0	1	
Parameter value	a_{24}	a_{23}	a_{22}	a_{21}	a_{20}	a_{19}	a_{18}	a_{17}	Aircraft ID
	a_{16}	a_{15}	a_{14}	a_{13}	a_{12}	a_{11}	a_{10}	a_9	
	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	
	0	0	0	m	l_{12}	l_{11}	l_{10}	l_9	M/I bit and LCI
	l_8	l_7	l_6	l_5	l_4	l_3	l_2	l_1	

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Note 3: Table 3-38 shows the case of a successful link handoff, as well as one SVC having been maintained.

3.2.2.5.2.7 Ground-Initiated Information Private Parameters

A ground LME shall use ground-initiated information parameters to inform one or more aircraft LMEs about that ground system's capabilities. Aircraft LMEs shall not send these parameters.

3.2.2.5.2.7.1 Frequency Support List

This parameter defines the list of frequencies, modulation schemes and associated ground stations supported in the coverage area of the originating ground station. The parameter shall consist of a list of 48-bit entries per Table 3-39. The modulation subfield (m bits) shall be encoded per Table 3-23. The frequency subfield (f bits) shall be encoded per Section 3.2.2.5.2.6.1.

The ground station address (g bits) shall be the DLS address encoded in a 32-bit field per Table 3-39. The ground DLS address shall be the DLS address of a ground station which can provide services using the specified frequency and modulation scheme.

No association shall be made between the operating parameters included in the transmitted XID frame and operating parameters of the ground station(s) listed. During frequency recovery the aircraft LME shall choose randomly a frequency from the list to re-acquire service.

Table 3-39: Frequency Support List

Parameter ID	1	0	0	0	0	0	0	1
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1
Parameter value	m_4	m_3	m_2	m_1	f_{12}	f_{11}	f_{10}	f_9
	f_8	f_7	f_6	f_5	f_4	f_3	f_2	f_1
	g_{22}	g_{23}	g_{24}	g_{25}	g_{26}	g_{27}	0	0
	g_{15}	g_{16}	g_{17}	g_{18}	g_{19}	g_{20}	g_{21}	0
	g_8	g_9	g_{10}	g_{11}	g_{12}	g_{13}	g_{14}	0
	g_1	g_2	g_3	g_4	g_5	g_6	g_7	0

3.2.2.5.2.7.2 Airport Coverage Indication Parameter

This parameter defines a list of four-character airport identifiers of airports for which the ground station can support communication with aircraft on the ground. Each four-character identifier shall be encoded as four 8-bit ISO IA5 characters per Table 3-40.

Table 3-40: Airport Coverage Indication Parameter

Parameter ID	1	1	0	0	0	0	0	1	
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	
Parameter value	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	first character
	b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1	
	c_8	c_7	c_6	c_5	c_4	c_3	c_2	c_1	
	d_8	d_7	d_6	d_5	d_4	d_3	d_2	d_1	fourth character

3.2.2.5.2.7.3 Nearest Airport Parameter

This parameter defines the four-character airport ID of the airport nearest the ground station. It shall be encoded as four 8-bit ISO IA5 characters per Table 3-41. The Nearest Airport parameter shall not be included in an XID if the Airport Coverage Identification is included.

Table 3-41: Nearest Airport Parameter

Parameter ID	1	1	0	0	0	0	1	1	
Parameter length	0	0	0	0	0	1	0	0	
Parameter value	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	first character
	b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1	
	c_8	c_7	c_6	c_5	c_4	c_3	c_2	c_1	
	d_8	d_7	d_6	d_5	d_4	d_3	d_2	d_1	fourth character

3.2.2.5.2.7.4 ATN Router NETs Parameter

This parameter defines a list of ATN air-ground routers identified by the "administration identifier" and "administration region selector" (ARS) subfields of their network entity titles (NETs). It shall be encoded per Tables 3-42a and 3-42b.

Table 3-42a: ATN Router NETs Parameter using Ground Network DTE Addresses

Parameter ID	1	1	0	0	0	1	0	0	
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	
Parameter value	a_{24}	a_{23}	a_{22}	a_{21}	a_{20}	a_{19}	a_{18}	a_{17}	administration identifier subfield
	a_{16}	a_{15}	a_{14}	a_{13}	a_{12}	a_{11}	a_{10}	a_9	
	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	
	r_{24}	r_{23}	r_{22}	r_{21}	r_{20}	r_{19}	r_{18}	r_{17}	administration region selector subfield
	r_{16}	r_{15}	r_{14}	r_{13}	r_{12}	r_{11}	r_{10}	r_9	
	r_8	r_7	r_6	r_5	r_4	r_3	r_2	r_1	

Table 3-42b: ATN Router NETs Parameter for Systems Using Ground DTE Addresses

Parameter ID	1	1	0	0	0	1	0	0	
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	
Parameter value	a_{24}	a_{23}	a_{22}	a_{21}	a_{20}	a_{19}	a_{18}	a_{17}	administration identifier subfield
	a_{16}	a_{15}	a_{14}	a_{13}	a_{12}	a_{11}	a_{10}	a_9	
	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	
	u_{24}	u_{23}	u_{22}	u_{21}	u_{20}	u_{19}	u_{18}	u_{17}	DSP Defined
	u_{16}	u_{15}	u_{14}	u_{13}	u_{12}	u_{11}	u_{10}	u_9	
	u_8	u_7	u_6	u_5	u_4	u_3	u_2	u_1	

U: DSP defined

3.2.2.5.2.7.5 Station Operator Mask Parameter

This parameter defines the station operator mask. It shall be encoded as a 27-bit mask in a 32-bit field per Table 3-43.

Table 3-43: Station Operator Mask Parameter

Parameter ID	1	1	0	0	0	1	0	1
Parameter length	0	0	0	0	0	1	0	0
Parameter value	g_{22}	g_{23}	g_{24}	g_{25}	g_{26}	g_{27}	0	0
	g_{15}	g_{16}	g_{17}	g_{18}	g_{19}	g_{20}	g_{21}	0
	g_8	g_9	g_{10}	g_{11}	g_{12}	g_{13}	g_{14}	0
	g_1	g_2	g_3	g_4	g_5	g_6	g_7	0

3.2.2.5.2.7.6 Timer TG3 Parameter

This parameter defines the value of the Timer TG3, (in half-seconds), that the ground LME is using. It shall be encoded as a pair of unsigned 16-bit integers per Table 3-44.

Table 3-44: Timer TG3 Parameter

Parameter ID	1	1	0	0	0	1	1	0	
Parameter length	0	0	0	0	0	1	0	0	
Parameter value	l_{16}	l_{15}	l_{14}	l_{13}	l_{12}	l_{11}	l_{10}	l_9	lower bound
	l_8	l_7	l_6	l_5	l_4	l_3	l_2	l_1	
	u_{16}	u_{15}	u_{14}	u_{13}	u_{12}	u_{11}	u_{10}	u_9	upper bound
	u_8	u_7	u_6	u_5	u_4	u_3	u_2	u_1	

3.2.2.5.2.7.7 Timer TG4 Parameter

This parameter defines the value of the Timer TG4, (in seconds), that the ground LME is using. It shall be encoded as an unsigned 16-bit integer per Table 3-45. A value of 0 shall mean that the ground is not using this timer.

Table 3-45: Timer TG4 Parameter

Parameter ID	1	1	0	0	0	1	1	1
Parameter length	0	0	0	0	0	0	1	0
Parameter value	v_{16}	v_{15}	v_{14}	v_{13}	v_{12}	v_{11}	v_{10}	v_9
	v_8	v_7	v_6	v_5	v_4	v_3	v_2	v_1

3.2.2.5.2.7.8 Ground Station Location Parameter

This parameter defines the position of the ground station. It shall be encoded per Tables 3-27 and 3-46.

Table 3-46: Ground Station Location Parameter

Parameter ID	1	1	0	0	1	0	0	0	
Parameter length	0	0	0	0	0	0	1	1	
Parameter value	v_{12}	v_{11}	v_{10}	v_9	v_8	v_7	v_6	v_5	latitude (v)
	v_4	v_3	v_2	v_1	h_{12}	h_{11}	h_{10}	h_9	
	h_8	h_7	h_6	h_5	h_4	h_3	h_2	h_1	longitude (h)

Note: Section 3.2.2.5.2.5.4 provides example of encoding scheme used.

3.2.2.5.3 VME Service System Parameters

The VME service shall implement the system parameters per Table 3-47 and detailed in Sections 3.2.2.5.3.1 through 3.2.2.5.3.5.

Table 3-47: VDL Management Entity System Parameters

Symbol	Parameter name		Minimum	Maximum	VDL Default	Increment
TG1 (air only)	~~Maximum~~ frequency dwell time		20 s	600 s	240 s	1 s
TG2	Maximum idle activity time	aircraft	120 s	360 s	240 s	1 s
		ground	10 min	4320 min	60 min	1 min
TG3 (ground only)	Maximum time between transmissions		100 s	120 s	Uniform between 100-120 s	0.5 s
TG4 (ground only)	Minimum time between GSIFs		100 s	120 s	None	1 s
TG5	Maximum link overlap time	initiating	0 s	255 s	20 s	1 s
		responding	0 s	255 s	60 s	1 s

3.2.2.5.3.1 Timer TG1 (~~Minimum~~ Frequency Dwell Time)

Timer TG1 shall be set to the ~~minimum~~ time (TG1) an aircraft LME dwells on a frequency while attempting to establish a link (in order to receive a valid uplink from at least one ground station). This timer shall be set by an aircraft LME (if it is not already running) when an aircraft tunes to a new frequency during a frequency search. It shall be canceled when a valid uplink is received from the preferred ground station. Upon expiration of the timer the aircraft station shall:

a. establish a link with one of the ground systems from which it has received a valid uplink; or
b. continue searching; or
c. if an aircraft does not detect any uplink traffic within TG1 seconds, it shall tune to the next frequency in the search table.

Notes:

1. *The duration of TG1 should be chosen to ensure a valid uplink is received from at least one ground system before the timer expires.*

2. *There is one Timer TG1 per LME.*

3. *In order to allow an aircraft station an opportunity to link to its most preferred ground system, Timer TG1 should not be canceled unless a valid uplink is received from its most preferred ground station.*

3.2.2.5.3.2 Timer TG2 (Maximum Idle Activity Time)

Timer TG2 shall be set to the maximum time (TG2) that an LME shall retain information on another station without receiving a transmission from it. The timer shall be started when a valid transmission is first received from a station and shall be restarted on each subsequent receipt of a valid transmission from that station. It shall never be canceled. If the Timer TG2 expires, an LME shall assume that the station is no longer reachable; if a link existed with that station, then link recovery shall be invoked.

Note: *There is one Timer TG2 for each station being monitored.*

3.2.2.5.3.3 Timer TG3 (Maximum Time Between Transmissions)

Timer TG3 shall be used at the ground station only. The timer shall be set to the maximum time (TG3) between transmissions on any frequency.

Timer TG3 shall be started when the ground station becomes operational and restarted on the transmission of any frame. This timer shall never be canceled. On expiration, if the ground station is operational, then it shall transmit a GSIF; the timer shall be restarted. The value to set the TG3 timer to shall consist of a fixed value equal to the minimum value plus a random value uniformly distributed between 0 and 20 seconds.

Note: There is one Timer TG3 per ground station.

3.2.2.5.3.4 Timer TG4 (Minimum Time Between GSIFs)

Timer TG4 shall be used at the ground station only. The timer shall be set to the minimum time (TG4) between transmissions of a GSIF on any frequency. Timer TG4 shall be started when the ground station becomes operational and restarted on the transmission of a GSIF. This timer shall never be canceled. On expiration, if the ground station is operational, then it shall transmit a GSIF; the timer shall be restarted. The value to set the TG4 timer to shall consist of a fixed value equal to the minimum value plus a random value uniformly distributed between 0 and 20 seconds.

Note: There is one Timer TG4 per ground station.

3.2.2.5.3.5 Timer TG5 (Maximum Link Overlap Time)

Timer TG5 shall be set to the maximum time that initiating and responding LMEs shall maintain the old link during handoffs. The LME initiating the handoff shall start its Timer TG5 when it receives an XID_RSP_HO. The LME responding to the handoff shall start its Timer TG5 when it transmits its XID_RSP_HO. The initiating LME shall never restart its Timer TG5; the responding LME shall restart its Timer TG5 if it retransmits an XID_RSP_HO. Timer TG5 shall be canceled if either the old or new link is prematurely disconnected. After TG5 expires, each LME shall silently disconnect its half of the old link.

Note: There is one Timer TG5 per LME.

3.2.2.5.4 Description of LME Procedures

The aircraft and ground LMEs shall use the XID frame types listed in Table 3-48 and the procedures described in the text below to provide a reliable connection between the aircraft and ground system. Frame collision processing (see Section 3.2.2.4.7) shall be applied before determining if a frame is illegal or unexpected (see Section 3.2.2.5.2.4.7). If an LME receives any valid XID frame from a system with which it does not have a link, it shall respond with an XID_LCR with the 'd' bit set to 1 in the Protocol Violation Cause Code.

3.2.2.5.4.1 Frequency Management Procedures

The aircraft LME shall use the following procedures to acquire a frequency on which reliable VDL services are available.

3.2.2.5.4.1.1 Frequency Search

The aircraft LME shall initiate the frequency search procedure on system initialization or after link disconnection, if it can no longer detect uplink VDL frames on the current frequency. It shall attempt to identify a frequency on which VDL service is available by tuning the radio to the common signaling channel (CSC) and to other frequencies on which it knows firsthand that VDL service is available. It shall scan until it detects a valid uplink VDL frame with an acceptable source address or until the TG1 timer expires, in which case it shall tune the radio to another frequency and continue to scan.

3.2.2.5.4.1.2 Frequency Recovery

The aircraft LME shall initiate the frequency recovery procedure if it can no longer establish a link on the current frequency or if the MAC entity indicates that the current frequency is congested. It shall tune the radio to an alternate frequency using the data in the Frequency Support List previously received on the current link.

3.2.2.5.4.2 Link Connectivity Procedures

The aircraft and ground LMEs shall use the following procedures to maintain connectivity across the VHF link:

a) ground station identification;
b) initial link establishment;
c) link parameter modification;
d) aircraft-initiated handoff;
e) aircraft-requested ground-initiated handoff;
f) ground-initiated handoff;
g) ground-requested aircraft-initiated handoff;
h) ground-requested broadcast handoff; and
i) autotune.

3.2.2.5.4.3 Ground Station Identification

A ground station shall send a GSIF by broadcasting an XID_CMD (P = 0) with parameters per Table 3-48 if its Timer TG3 expires (meaning that it has not transmitted any frame in TG3 seconds) or if its TG4 timer expires (meaning that it has not sent a GSIF in TG4 seconds). If the ground station offers VDL service, the operator of that ground station shall ensure that, besides transmitting GSIFs on the service frequency, GSIFs are transmitted on the CSC. Aircraft LMEs receiving a GSIF shall process its content to identify the functionality of the ground station as well as the correct operational parameters to be used when communicating with it. Aircraft LMEs which have a connection with the transmitting ground station shall process only informational

Table 3-48a: XID Parameters

			GSIF	**Air initiated link establishment**		**Link parameter modification**	
	Source address		Ground station	Aircraft	New ground station	Current Ground station	Aircraft
	Destination address		All aircraft	Proposed ground station	Aircraft	Aircraft	Current ground station
XID parameters	**GI**	**PI**	**GSIF (P=0)**	**XID_CMD_LE (P=1)**	**XID_RSP_LE (F=1)**	**XID_CMD_LPM (P=1)**	**XID_RSP_LPM (F=1)**
Public parameters							
Parameter set ID	80h	01h	M	M	M	N/A	N/A
Procedure classes	80h	02h	M	M	M	N/A	N/A
HDLC options	80h	03h	M	M	M	N/A	N/A
N1-downlink	80h	05h	O	N/A	O	N/A	N/A
N1-uplink	80h	06h	O	N/A	O	N/A	N/A
k-downlink	80h	07h	O	N/A	O	N/A	N/A
k-uplink	80h	08h	O	N/A	O	N/A	N/A
Timer T1 - downlink	80h	09h	O	N/A	O	N/A	N/A
Counter N2	80h	0Ah	O	N/A	O	N/A	N/A
Timer T2	80h	0Bh	O	N/A	O	N/A	N/A
Private parameters							
Parameter set ID	F0h	00h	M	M	M	M	M
Connection management	F0h	01h	N/A	M	M	N/A	N/A
SQP	F0h	02h	N/A	O	O	O	O
XID sequencing	F0h	03h	N/A	M	M	M	M
AVLC specific options	F0h	04h	M	M	M	N/A	N/A
Expedited SN connection	F0h	05h	N/A	O	O	N/A	N/A
LCR cause	F0h	06h	N/A	N/A	N/A	N/A	N/A
Modulation support	F0h	81h	N/A	M	N/A	N/A	N/A
Alternate ground stations	F0h	82h	N/A	O	N/A	N/A	N/A
Destination airport	F0h	83h	N/A	O	N/A	N/A	N/A
Aircraft location	F0h	84h	N/A	O	N/A	N/A	N/A
Autotune frequency	F0h	40h	N/A	N/A	O	N/A	N/A
Repl. ground station	F0h	41h	N/A	N/A	O	N/A	N/A
Timer T4	F0h	42h	O	N/A	O	O	N/A
MAC persistence	F0h	43h	O	N/A	O	O	N/A
Counter M1	F0h	44h	O	N/A	O	O	N/A
Timer TM2	F0h	45h	O	N/A	O	O	N/A
Timer TG5	F0h	46h	O	N/A	O	O	N/A
Timer T3min	F0h	47h	O	N/A	O	N/A	N/A
Address filter	F0h	48h	N/A	N/A	N/A	N/A	N/A
Broadcast connection	F0h	49h	N/A	N/A	N/A	N/A	N/A
Frequency support	F0h	C0h	O	N/A	O	N/A	N/A
Airport coverage	F0h	C1h	M1	N/A	O2	N/A	N/A
Nearest airport ID	F0h	C3h	M1	N/A	O2	N/A	N/A
ATN router NETs	F0h	C4h	M	N/A	M	N/A	N/A
System mask	F0h	C5h	M	N/A	M	N/A	N/A
TG3	F0h	C6h	O	N/A	O	N/A	N/A
TG4	F0h	C7h	O	N/A	O	N/A	N/A
Ground station location	F0h	C8h	O	N/A	O	N/A	N/A

Note: See Key at the end of Table 3-48c.

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Table 3-48b: XID Parameters

			Ground initiated handoff		**Air initiated handoff**	
	Source address		Proposed ground station	Aircraft	Aircraft	New ground Station
	Destination address		Aircraft	New Ground station	Proposed ground station	Aircraft
XID parameters	**GI**	**PI**	**XID_CMD_HO (P=1)**	**XID_RSP_HO (F=1)**	**XID_CMD_HO (P=1)**	**XID_RSP_HO (F=1)**
Public parameters						
Parameter set ID	80h	01h	O	O	O	O
Procedure classes	80h	02h	O	O	O	O
HDLC options	80h	03h	O	O	O	O
N1-downlink	80h	05h	O	N/A	N/A	O
N1-uplink	80h	06h	O	N/A	N/A	O
k-downlink	80h	07h	O	N/A	N/A	O
k-uplink	80h	08h	O	N/A	N/A	O
Timer T1 - downlink	80h	09h	O	N/A	N/A	O
Counter N2	80h	0Ah	O	N/A	N/A	O
Timer T2	80h	0Bh	O	N/A	N/A	O
Private parameters						
Parameter set ID	F0h	00h	M	M	M	M
Connection management	F0h	01h	M	M	M	M
SQP	F0h	02h	O	O	O	O
XID sequencing	F0h	03h	M	M	M	M
AVLC specific options	F0h	04h	O	O	O	O
Expedited SN connection	F0h	05h	O	O	O	O
LCR cause	F0h	06h	N/A	N/A	N/A	N/A
Modulation support	F0h	81h	N/A	N/A	N/A	N/A
Alternate grnd stations	F0h	82h	N/A	N/A	O	N/A
Destination airport	F0h	83h	N/A	O	O	N/A
Aircraft location	F0h	84h	N/A	O	O	N/A
Autotune frequency	F0h	40h	N/A	N/A	N/A	O
Repl. ground station	F0h	41h	O	N/A	N/A	O
Timer T4	F0h	42h	O	N/A	N/A	O
Mac persistence	F0h	43h	O	N/A	N/A	O
Counter M1	F0h	44h	O	N/A	N/A	O
Timer TM2	F0h	45h	O	N/A	N/A	O
Timer TG5	F0h	46h	O	N/A	N/A	O
Timer T3min	F0h	47h	O	N/A	N/A	O
Address filter	F0h	48h	N/A	N/A	N/A	N/A
Broadcast connection	F0h	49h	N/A	N/A	N/A	N/A
Frequency support	F0h	C0h	O	N/A	N/A	O
Airport coverage	F0h	C1h	O2	N/A	N/A	O2
Nearest airport ID	F0h	C3h	O2	N/A	N/A	O2
ATN router NETs	F0h	C4h	M	N/A	N/A	O
System mask	F0h	C5h	O	N/A	N/A	M
TG3	F0h	C6h	O	N/A	N/A	O
TG4	F0h	C7h	O	N/A	N/A	O
Ground station location	F0h	C8h	O	N/A	N/A	O

Note: See Key at the end of Table 3-48c.

Table 3-48c: XID Parameters

			Air requested handoff	**Ground requested handoff**	**Ground requested broadcast**	**Link connection rejection**
	Source address		Aircraft	Current ground station	New ground station	Any station
	Destination address		Current or proposed ground station	Aircraft	All aircraft	Any station
XID parameters	**GI**	**PI**	**XID_CMD_HO (P=0)**	**XID_CMD_HO (P=0)**	**XID_CMD_HO (P=0)**	**XID_RSP_LCR** **XID_CMD_LCR**
Public parameter						
Parameter set ID	80h	01h	N/A	O	O	N/A
Procedure classes	80h	02h	N/A	O	O	N/A
HDLC options	80h	03h	N/A	O	O	N/A
N1-downlink	80h	05h	N/A	O	O	N/A
N1-uplink	80h	06h	N/A	O	O	N/A
k-downlink	80h	07h	N/A	O	O	N/A
k-uplink	80h	08h	N/A	O	O	N/A
Timer T1 - downlink	80h	09h	N/A	O	O	N/A
Counter N2	80h	0Ah	N/A	O	O	N/A
Timer T2	80h	0Bh	N/A	O	O	N/A
Private parameters						
Parameter set ID	F0h	00h	M	M	M	M
Connection management	F0h	01h	M	M	M	M
SQP	F0h	02h	N/A	N/A	N/A	N/A
XID sequencing	F0h	03h	M	M	M	M
AVLC specific options	F0h	04h	N/A	O	O	N/A
Expedited SN connection	F0h	05h	N/A	N/A	N/A	N/A
LCR cause	F0h	06h	N/A	N/A	N/A	M
Modulation support	F0h	81h	N/A	N/A	N/A	N/A
Alternate ground stations	F0h	82h	O	N/A	N/A	N/A
Destination airport	F0h	83h	O	N/A	N/A	N/A
Aircraft location	F0h	84h	O	N/A	N/A	N/A
Autotune frequency	F0h	40h	N/A	O	N/A	N/A
Repl. ground station	F0h	41h	N/A	O	N/A	N/A
Timer T4	F0h	42h	N/A	O	O	N/A
MAC persistence	F0h	43h	N/A	O	O	N/A
Counter M1	F0h	44h	N/A	O	O	N/A
Timer TM2	F0h	45h	N/A	O	O	N/A
Timer TG5	F0h	46h	N/A	O	O	N/A
Timer T3min	F0h	47h	N/A	O	O	N/A
Address filter	F0h	48h	N/A	N/A	M	N/A
Broadcast connection	F0h	49h	N/A	N/A	M	N/A
Frequency support	F0h	C0h	N/A	O	O	N/A
Airport coverage	F0h	C1h	N/A	N/A	O2	N/A
Nearest airport ID	F0h	C3h	N/A	N/A	O2	N/A
ATN router NETs	F0h	C4h	N/A	O	M	N/A
System mask	F0h	C5h	N/A	O	O	N/A
TG3	F0h	C6h	N/A	O	O	N/A
TG4	F0h	C7h	N/A	O	O	N/A
Ground station location	F0h	C8h	N/A	O	O	N/A

Key for Tables 3-48a, b, and c above:

Abbreviations used:

GI = ISO 8885 Group identifier,
PI = ISO 8885 Parameter identifier
M = Mandatory,
O = Optional,
N/A = Not applicable,
h = hexadecimal

Notes For Tables 3-48a, b, and c:

1. *In a GSIF XID frame it is mandatory to include either the Airport Coverage Indication parameter or the Nearest Airport Identifier parameter but not both (see Section 3.2.2.5.2.7.3).*

2. *Where the Airport Coverage Indication parameter and the Nearest Airport Identifier parameter are marked as optional, either parameter may be included in the frame or neither but not both.*

parameters and those parameters specified for an XID_CMD_LPM (Link Parameter Modification) per Table 3-48.

3.2.2.5.4.4 Link Establishment

The aircraft LME shall initiate the link establishment procedure with a ground station only to establish an initial link with the ground system. An aircraft transmitting or receiving a DM frame shall initiate link establishment if no link remains.

3.2.2.5.4.4.1 Aircraft Initiation

The aircraft LME shall choose a ground station with which it wishes to establish a link based on the signal quality of all received uplink frames and on information in any received GSIFs. It shall then attempt to establish a link with the chosen ground station by sending an XID_CMD_LE (P=1) frame. This frame shall include the mandatory parameters per Table 3-48 and also any optional parameters for which the aircraft does not wish to use the default value. If the aircraft LME has received a GSIF from the ground station to which it is transmitting the XID_CMD_LE (P=1), then it shall use the parameters as declared; otherwise, it shall use the default parameters.

3.2.2.5.4.4.2 General Ground Response

If the ground LME receives the XID_CMD_LE, it shall confirm link establishment by sending an XID_RSP_LE frame containing the parameters per Table 3-48. The ground LME shall include in the XID_RSP_LE any optional parameters for which it is not using the default values. If the XID_RSP_LE includes the Autotune parameter then the Replacement Ground Station List parameter shall be included indicating the ground stations on the new frequency with which the aircraft LME can establish a new link using the operating parameters specified in the XID_RSP_LE. If the XID_RSP_LE does not include the Autotune parameter, the ground LME shall include the Replacement Ground Station List parameter if it wishes to indicate the ground stations that can be reached on the current frequency using the same operating parameters as the transmitting station.

3.2.2.5.4.4.3 Exceptional Cases

If an LME receiving the XID_CMD_LE cannot establish the link with the sending LME, then it shall transmit an XID_RSP_LCR (F=1) instead of an XID_RSP_LE (F=1).

If the parameters in the XID_RSP_LE from the ground LME are not acceptable to the aircraft LME, then the aircraft LME shall transmit a DISC to the ground.

If the Autotune parameter is included in the XID_RSP_LE and the aircraft LME is unable to perform the autotune, then the aircraft shall respond with an XID_CMD_LCR (P = 0); the link established on the current frequency shall not be affected.

While waiting for a response to an XID_CMD_LE, an aircraft LME receiving any unicast frame other than a TEST or an XID shall retransmit the XID_CMD_LE instead of transmitting a DM.

Note: See Section 3.2.2.4.8 on the processing of an XID_CMD.

3.2.2.5.4.5 Link Parameter Modification (LPM)

3.2.2.5.4.5.1 Ground Initiation

The ground LME shall request a modification of an existing link connection's parameters by sending an XID_CMD_LPM (P=1) to the aircraft LME containing the parameters per Table 3-48.

3.2.2.5.4.5.2 General Aircraft Response

The aircraft LME shall acknowledge with an XID_RSP_LPM containing the parameters per Table 3-48.

Note: If Counter N2 is exceeded for the XID_CMD_LPM, the ground LME should attempt to handoff via another station before disconnecting the link to the aircraft.

3.2.2.5.4.6 Aircraft-Initiated Handoff

If an aircraft LME implements this function, then it shall set the i bit in the AVLC Specific Options parameter to 1; otherwise, it shall set the i bit to 0.

Note: It is strongly recommended that VDL Mode 2 avionics support Aircraft Initiated Handoff requirements.

3.2.2.5.4.6.1 Aircraft Handoff

Once the aircraft LME has established a link to a ground station, it shall monitor the VHF signal quality on the link and the transmissions of the other ground stations. The aircraft LME shall establish a link to a new ground station if any of the following events occur:

1. the VHF signal quality on the current link is poor and the signal quality of another ground station is significantly better;
2. the Counter N2 is exceeded on any frame sent to the current ground station;
3. the Timer TG2 expires for the current link; or
4. the Timer TM2 expires. In this case, the aircraft shall autonomously tune to an alternate frequency (provided in a frequency support list) before initiating the handoff.

3.2.2.5.4.6.2 Site Selection Preference

From among those ground stations with acceptable link quality, the aircraft LME shall prefer to handoff to a ground station which indicates (in the GSIF) accessibility to the air-ground router(s) to which the aircraft DTE has subnetwork connections.

Note: If an aircraft has commenced approach to its destination airport and its current link is with a ground station that does not offer service at that airport, it should handoff to a ground station which indicates in its Airport Coverage Indication parameter that it offers service at that airport.

3.2.2.5.4.6.3 Interaction of LMEs

When an aircraft VME hands off from a ground station in one ground system (and thus associated with one LME) to a ground station in another ground system (and thus associated with a different LME in the aircraft), the new LME shall use the link establishment procedures and the old LME shall send a DISC when directed by the VME.

Note: *Optimally the old link should not be disconnected until after the new link is capable of carrying application data.*

3.2.2.5.4.6.4 General Ground Response

If the ground LME receives the XID_CMD_HO, it shall confirm the link handoff by sending an XID_RSP_HO frame containing the parameters per Table 3-48. The ground LME shall include in the XID_RSP_HO the optional parameters for which it is not using the default values. If the XID_RSP_HO includes the Autotune parameter then the Replacement Ground Station List parameter shall be included indicating the ground stations with which the aircraft LME can establish a new link on the new frequency, using the operating parameters specified in the XID_RSP_HO. If the XID_RSP_HO does not include the Autotune parameter, the ground LME shall include the Replacement Ground Station List parameter if it wishes to indicate the ground stations which can be reached on the current frequency using the same operating parameters as the transmitting station.

3.2.2.5.4.6.5 Disconnecting Old Link

If the new and old ground stations are associated with different systems, then the procedures of Section 3.2.2.5.4.6.3 shall be followed. Otherwise, the aircraft LME shall set the Timer TG5 when it receives the XID_RSP_HO. The ground LME shall set the Timer TG5 after it transmits the XID_RSP_HO. Both stations shall continue to operate on the old link until their respective Timer TG5 expires, after which each will consider the link disconnected without sending or receiving a DISC.

3.2.2.5.4.6.6 Exceptional Cases

If the ground LME cannot satisfy the XID_CMD_HO, then it shall transmit an XID_RSP_LCR instead of an XID_RSP_HO; the current link shall not be affected.

While waiting for a response to an XID_CMD_HO, an aircraft LME receiving any unicast frame other than a TEST or an XID from any ground station other than the current station shall retransmit the XID_CMD_HO.

If the Counter N2 is exceeded on the XID_CMD_HO, the aircraft LME shall attempt to handoff to another ground station; the current link shall not be affected.

If the aircraft LME cannot perform the autotune, it shall transmit an XID_CMD_LCR (P=0); the current connection shall not be affected.

If the parameters in the XID_RSP_HO are not acceptable to the aircraft LME, then the aircraft LME shall transmit a DISC to the ground on the new link.

Note: See Section 3.2.2.4.8 on the processing of an XID_CMD.

3.2.2.5.4.7 Aircraft-Requested Ground-Initiated Handoff

An aircraft LME shall not perform this function when its peer LME does not support handoff initiation. An aircraft LME shall only perform this function if the current and proposed ground stations are both managed by their peer LME.

3.2.2.5.4.7.1 Aircraft Action

For an aircraft LME to request the ground LME to initiate a handoff, it shall send an XID_CMD_HO (P=0) addressed to its current or proposed ground station with the parameters per Table 3-48. During this procedure the current link shall not be affected until the aircraft LME receives an XID_CMD_HO (P=1).

3.2.2.5.4.7.2 General Ground Response

If the ground LME receives the XID_CMD_HO, it shall commence a ground-initiated handoff from the current ground station to the proposed ground station. The ground LME shall only transmit the XID_CMD_HO (P=1) once per XID_CMD_HO (P=0) request that it receives.

3.2.2.5.4.7.3 Exceptional Cases

If the ground system cannot initiate the handoff, it shall send an XID_CMD_LCR (P=0); the current link shall not be affected.

Note: If the Counter N2 is exceeded for the XID_CMD_HO, the aircraft LME should attempt to request to handoff to another station before disconnecting all links to the ground and restarting link establishment.

3.2.2.5.4.8 Ground-Initiated Handoff

If a ground LME implements this section, then it shall set the i bit in the AVLC Specific Options parameter to 1; otherwise, it shall set the i bit to 0.

3.2.2.5.4.8.1 Ground Action

To command an aircraft, to which a link exists, to establish a new link to a proposed ground station on the same frequency, the ground LME shall send via the ground station an XID_CMD_HO (P=1) to the aircraft with parameters per Table 3-48. If the ground LME will accept a handoff to other ground stations, the XID_CMD_HO shall include the Replacement

Ground Station List parameter specifying the link layer address of those other stations. Any operating parameters in the XID_CMD_HO (either modification or informational) shall be valid for the transmitting station and for all ground stations listed in the Replacement Ground Station List parameter, except the Airport Coverage Indication parameter and Nearest Airport ID parameter which are only valid for the transmitting ground station.

3.2.2.5.4.8.2 General Aircraft Response

The aircraft LME shall respond by sending an XID_RSP_HO with parameters per Table 3-48 to either the proposed ground station or to its preferred ground station if the XID_CMD_HO included the Replacement Ground Station List parameter.

3.2.2.5.4.8.3 Disconnecting Old Link

The aircraft LME shall set the Timer TG5 after it transmits the XID_RSP_HO. The ground LME shall set the Timer TG5 when it receives the XID_RSP_HO. Although new traffic will be sent over the new link, the old link shall not be disconnected immediately to allow any old traffic to be delivered.

3.2.2.5.4.8.4 Exceptional Cases

If the aircraft LME cannot accept the handoff request, it shall respond with an XID_RSP_LCR; the old link shall not be affected.

While waiting for a response to an XID_CMD_HO, a ground LME receiving any unicast frame other than a TEST or an XID from the aircraft shall retransmit the XID_CMD_HO.

If the parameters in the XID_RSP_HO are not acceptable to the ground LME, then the ground LME shall transmit a DISC to the aircraft on the new link.

Notes:

1. *See Section 3.2.2.4.8 on the processing of an XID_CMD.*

2. *If Counter N2 is exceeded for the XID_CMD_HO, the ground LME should attempt to handoff via another station before deleting all links to the aircraft.*

3.2.2.5.4.9 Ground-Requested Aircraft-Initiated Handoff

A ground LME shall not perform this function with aircraft that do not support handoff initiation.

3.2.2.5.4.9.1 Ground Action

For the ground LME to request an aircraft to initiate a handoff, it shall send an XID_CMD_HO (P=0) on the current link with parameters per Table 3-48. The parameters in the XID (both modification and informational) are valid for all ground stations listed in the Replacement Ground Station List. It shall only include operational parameters if it also includes the Replacement Ground Station List parameter. If the Autotune parameter is included, then the Replacement Ground Station List parameter shall apply to the new frequency.

3.2.2.5.4.9.2 General Aircraft Response

If the aircraft LME receives the XID_CMD_HO, it shall commence an aircraft-initiated handoff to a ground station, preferably one listed in the Replacement Ground Station List parameter.

> *Note: See Section 3.2.2.4.8 on the processing of an XID_CMD.*

3.2.2.5.4.9.3 Exceptional Cases

If the aircraft LME cannot initiate the handoff, it shall send an XID_CMD_LCR (P=0); the current link shall not be affected. If the Autotune parameter is included in the XID_CMD_HO (P=0), the aircraft shall retransmit on the new frequency the XID_CMD_HO (P=1) using the normal retransmission procedures; otherwise, it shall only transmit the XID_CMD_HO (P=1) once per received XID_CMD_HO (P=0).

> *Note: If Counter N2 is exceeded for the XID_CMD_HO, the ground LME should attempt to request a handoff via another station before disconnecting all links to the aircraft.*

3.2.2.5.4.10 Ground-Requested Broadcast Handoff

If the ground LME broadcasts link handoffs then it shall set the b_1 bit in the AVLC Specific Options parameter to 1; otherwise, it shall set the b_1 bit to 0. If the ground LME supports broadcast subnetwork connection handoff, the ground LME shall also support broadcast link handoffs and shall set the b_1 and b_s bits in the AVLC Specific Options parameter to 1; otherwise, it shall set the b_s bit to 0.

Notes:
*1. See **Table 3-18** for definition of b_1 and b_2 bits.*
2. It is strongly recommended that VDL Mode 2 avionics support Ground Requested Broadcast Handoff requirements.

~~*Note: See Table 3-18 for definition of b_1 and b_s bits.*~~

3.2.2.5.4.10.1 Ground Action

If the ground LME supports broadcast link handoffs, for each aircraft that indicates it supports broadcast link handoff, the ground LME shall confirm the link handoff by including the Broadcast Connection parameter per Table 3-48. If the ground LME supports broadcast subnetwork connection management, for each aircraft that indicates it supports broadcast subnetwork connection management, the ground LME shall confirm the link handoff and the subnetwork connection maintenance by including the Broadcast Connection parameter per Table 3-48.

3.2.2.5.4.10.2 Aircraft Response

The LME in each aircraft shall process received broadcast XID_CMD_HO (P=0) and determine if the ground LME had performed a broadcast link recovery (and possibly an expedited subnetwork recovery) for it. It shall do this by verifying that the Ground Station Address Filter parameter contains the DLS address of the ground station that it is connected to and that a Broadcast Connection parameter exists containing its aircraft address. Aircraft LMEs supporting broadcast recovery shall consider that a link handoff has occurred with the new link having the same parameters as the old link (as modified by the parameters in the broadcast XID). The old link shall be disconnected immediately.

The Broadcast Connection parameter shall include the subnetwork connection information (i.e., the M/I and LCI subfields) for only those subnetwork connections between the aircraft DTE and the peer ground DTEs that the ground LME maintained. Aircraft LMEs supporting broadcast subnetwork connection management shall process the remainder of the Broadcast Connection parameter to determine which subnetwork connections the ground LME maintained. For those subnetwork connections associated with the logical channels on the old link that the ground LME maintained, the aircraft DTE shall consider as if the CALL REQUEST and CALL CONFIRMATION sent on the old link were resent on the new link (except that the M/I bit in the Broadcast Connection parameter shall supersede the value in the previous CALL CONFIRMATION). At this point the aircraft DTE, ground DCE, and ground DTE shall be initialized. If the Broadcast Connection parameter indicates that the ground was not able to maintain a subnetwork connection (i.e., a particular LCI is not mentioned in the Broadcast Connection parameter), the aircraft shall explicitly establish this subnetwork connection per Section 3.2.3.6.3.3.1.

3.2.2.5.4.10.3 Exceptional Cases

If the aircraft LME does not support broadcast recovery, but the ground LME performed a broadcast link recovery for it, then the aircraft LME shall perform either an air-initiated link handoff, (if the aircraft LME supports same) or request a ground-initiated link handoff.

If the aircraft LME finds the new ground station unacceptable, it shall perform an air-initiated handoff (if the aircraft LME supports same) or request a link handoff.

If the Ground Station Address Filter parameter does not equal the DLS address of a link that the aircraft LME has or if no aircraft identifier subfield in a Broadcast Connection parameter equals its aircraft address, the aircraft LME shall not process the ground requested broadcast handoff.

If the aircraft LME supports broadcast link handoffs but does not support broadcast subnetwork connection management and the Broadcast Connection field is implemented per Table 3-48, the aircraft shall explicitly establish its subnetwork connections.

If the Broadcast Connection parameter indicates that a subnetwork connection was maintained, but the aircraft LME does not recognize that subnetwork connection, then the aircraft DTE shall transmit a CLEAR REQUEST for each unrecognized subnetwork connection.

3.2.2.5.4.11 Ground-Commanded Autotune

This section summarizes the autotune details found in Sections 3.2.2.5.4.3, 3.2.2.5.4.5, and 3.2.2.5.4.8.

3.2.2.5.4.11.1 Ground Action

To command an aircraft LME to handoff to a ground station on a different frequency, the ground LME shall include the Autotune and Replacement Ground Station List parameters in an XID it sends during a link establishment or handoff procedure.

3.2.2.5.4.11.2 General Aircraft Response

On receipt of an XID commanding an autotune, the aircraft LME shall retune the aircraft radio to the new frequency and commence an aircraft-initiated handoff to the chosen ground station.

3.2.2.5.4.11.3 Exceptional Cases

If the aircraft LME cannot perform the autotune, it shall transmit an XID_CMD_LCR (P = 0); the current link shall not be affected.

3.2.2.5.4.12 Expedited Subnetwork Connection Management

If an LME implements this function, then it shall set the v bit in the AVLC Specific Options and in the Connection Management parameters to 1; otherwise it shall set them to 0. This function shall only be applicable for the link establishment, air-initiated handoff, and ground-initiated handoff processes.

Note: See Table 3-18 for definition of v bit.

3.2.2.5.4.12.1 Initiating Station of Subnetwork Connection Management

To perform an expedited subnetwork connection establishment or maintenance, the initiating LME shall include in the XID_CMD the Expedited Network Connection parameter for each subnetwork connection that needs to be established or maintained. The procedures for an expedited link establishment and maintenance shall be the same as outlined in Sections 3.2.2.5.4.4, 3.2.2.5.4.6, and 3.2.2.5.4.8.

3.2.2.5.4.12.2 General Responder Action

If the responding LME receives an XID_CMD with one or more Expedited Network Connection parameters, it shall confirm subnetwork connection establishment or maintenance by sending an XID_RSP containing the parameters per Table 3-48. The responding LME shall attempt to establish or maintain the specified subnetwork connections as outlined in Section 3.2.3.6.3. The responding LME shall include in the XID_RSP the CALL CONFIRMATION or CLEAR REQUEST responses (i.e. in the Expedited Network Connection parameter) and any optional parameters for which it is not using the default values. The ground LME shall not process the Expedited Network Connection parameters if it includes the Autotune parameter in the XID_RSP.

3.2.2.5.4.12.3 Exceptional Cases

If the responding LME cannot support the Expedited Network Connection establishment or maintenance but can support the link establishment or handoff, it shall respond with XID_RSP with the connection management v bit set to 0 and shall not include the Expedited Network Connection parameters in the XID_RSP.

If T3min expires, the responding LME shall include all responses (i.e. CALL CONFIRMATION or CLEAR REQUEST) that it has received up to that point in the XID_RSP. Any late responses from respective DTE(s) shall be sent to the initiating LME in INFO frames.

Note: All XID_CMD retransmissions will cause the responding LME to respond with the same XID_RSP without further processing. All late subnetwork connection responses from ground DTEs will not be included in the retransmitted XID_RSP.

3.2.3 Subnetwork Layer Protocols and Services

3.2.3.1 Architecture

The subnetwork layer protocol used across the VHF A/G subnetwork is referred to formally as a subnetwork access protocol (SNAcP) and shall conform to ISO 8208, except as noted below. The SNAcP is referred to within this document as the subnetwork protocol. If there are any differences between this document and the cited specifications, this document shall have precedence. On the A/G interface, the aircraft subnetwork entity shall act as a DTE and the ground subnetwork entity shall act as a DCE.

Note: *Refer to ISO 8208 for information on the DTE-DCE or DTE-DTE relationships.*

3.2.3.1.1 Access Points

The Subnetwork Service Access Point (SNSAP) shall be uniquely identified by the subnetwork Data Terminal Equipment (DTE) address. SNSAPs shall define the Subnetwork Point of Attachment (SNPA) used by the service primitives that define the subnetwork service to the subnetwork dependence convergence protocol.

3.2.3.1.2 ACARS Over AVLC (AOA)

AOA is a service that encapsulates ACARS messages within an AVLC frame for transmission over the VDL Mode 2 system. The VDL Mode 2 system is capable of supporting multiple network protocols over AVLC (link layer), enabling both AOA and ATN services to co-exist over the VDL Mode 2 media. The data link layer frame can carry either packet type, with a signature component for the host to differentiate between the different types of frames. AOA is provided as a service to the current users of the datalink services to support the increased demand and to promote a smoother transition to the full ATN service.

The signature component identifier in the ISO/IEC 9577 header. ISO 9577 Initial Protocol Identifier (IPI) byte encoding of all-ones (0xFF) is reserved by ISO/IEC TR 9577 to allow for the specification of additional subnetwork protocols beyond those explicitly defined in the ISO document. When this form of IPI encoding is employed, a second octet (the Extended Initial Protocol Identifier (EIPI)) is used to specify the actual subnetwork protocol in use. The "ACARS Over AVLC" (AOA) subnetwork protocol (used to provide backwards compatibility for ACARS applications to operate over VDL Mode 2) currently specifies the EIPI encoding of 0xFF.

The IPI and EIPI shall be set in the first two octets of the uplink and downlink Information frame as illustrated in **Table 3-49a**. The IPI set to “1111 1111” indicates that the IPI is extended by one octet. The second octet, EIPI set to “1111 1111” indicates the payload, or user data, is an ACARS 618/620 block.

Note: The values for the IPI and EIPI are the same for both uplink and downlink frames.

Table 3-49a: AOA Message Format within the AVLC frame

DESCRIPTION		Octet No.	BIT NUMBER							
			8	7	6	5	4	3	2	1
FLAG		0	0	1	1	1	1	1	1	0
ISO 3309:1996(E) [3]	Destination Address Field	1	d_{22}	d_{23}	d_{24}	d_{25}	d_{26}	d_{27}	A/G	0
		2	d_{15}	d_{16}	d_{17}	d_{18}	d_{19}	d_{20}	d_{21}	0
		3	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	0
		4	d_1	d_2	d_3	d_4	d_5	d_6	d_7	0
	Source Address Field	5	s_{22}	s_{23}	s_{24}	s_{25}	s_{26}	s_{27}	C/R	0
		6	s_{15}	s_{16}	s_{17}	s_{18}	s_{19}	s_{20}	s_{21}	0
		7	s_8	s_9	s_{10}	s_{11}	s_{12}	s_{13}	s_{14}	0
		8	s_1	s_2	s_3	s_4	s_5	s_6	s_7	1
Link Control Field		9				P/F				
Information Field	Initial Protocol Identifier (IPI)	10	1	1	1	1	1	1	1	1
	Extended IPI	11	1	1	1	1	1	1	1	1
	User Data	12..N-2	ARINC 618/620 Message							
Frame Check Sequence Field		N-1	fcs_9	fcs_{10}	MOST SIGNIFICANT OCTET				fcs_{15}	fcs_{16}
		N	fcs_1	fcs_2	LEAST SIGNIFICANT OCTET				fcs_7	fcs_8
Flag		N+1	0	1	1	1	1	1	1	0
Reference VDL SARPs, Figure 6-2, VDL Technical Manual Figure 5-1										

~~AOA is a service that encapsulates ACARS messages within an AVLC frame for transmission over the VDL Mode 2 system. The VDL Mode 2 system is capable of supporting multiple network protocols over AVLC (link layer), enabling both AOA and ATN services to co-exist over the VDL Mode 2 media. The data link layer frame can carry either packet type, with a signature component for the host to differentiate between the two types of frames. AOA is provided as a service to the current users of the datalink services to support the increased demand and to promote a smoother transition to the full ATN service.~~

3.2.3.1.3 Flight Information Services-Broadcast (FIS-B)

RTCA SC-195 has developed Minimum Aviation System Performance Standards (MASPS) for Flight Information Services-Broadcast (FIS-B), an automated, media-independent digital data link system. The system will provide non-control, advisory information needed by pilots to operate more safely and efficiently in the National Airspace System and in international airspace.

FIS provides to pilots the necessary weather graphics and text, Special Use Airspace (SUA) information, Notices to Airmen (NOTAMs), and other information.

This broadcast data provides connectionless unacknowledged protocol services. This broadcast data link service supports efficiency in spectrum use since there is no need to separately transmit the same information to multiple receivers.

One of the FIS-B media is the VDL Mode 2 subnetwork; consequently, there's a need to uniquely identify this service from other services that are or might be carried by VDL Mode 2, such as ATN, AOA and future applications.

The FIS-B MASPS specify a field from within a VDL Mode 2 UI frame to uniquely identify a FIS-B message in accordance with the recommendations of ISO/IEC TR 9577. This field facilitates subnetwork access protocol identification in the event of multiple concurrent subnetwork use. The IPI is set to the 0xFF and, FIS-B has selected the EIPI encoding of 0xFE (11111110) as a frame type identifier.

The IPI and EIPI shall be set in the first two octets of the uplink Un-numbered Information broadcast frame as illustrated in Table 3-49b. The IPI set to "1111 1111" indicates that the IPI is extended by one octet. The second octet, EIPI set to "1111 1110" indicates the payload, or user data, is a FIS-B block.

Table 3-49b: FIS-B Message Format

DESCRIPTION		Octet No.	BIT NUMBER							
			8	7	6	5	4	3	2	1
FLAG		0	0	1	1	1	1	1	1	0
ISO 3309:1996(E) [3]	Destination Address Field	1	d_{22}	d_{23}	d_{24}	d_{25}	d_{26}	d_{27}	A/G	0
		2	d_{15}	d_{16}	d_{17}	d_{18}	d_{19}	d_{20}	d_{21}	0
		3	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	0
		4	d_1	d_2	d_3	d_4	d_5	d_6	d_7	0
	Source Address Field	5	s_{22}	s_{23}	s_{24}	s_{25}	s_{26}	s_{27}	C/R	0
		6	s_{15}	s_{16}	s_{17}	s_{18}	s_{19}	s_{20}	s_{21}	0
		7	s_8	s_9	s_{10}	s_{11}	s_{12}	s_{13}	s_{14}	0
		8	s_1	s_2	s_3	s_4	s_5	s_6	s_7	1
Link Control Field		9				P/F				
Un-numbered Information Field	Initial Protocol Identifier (IPI)	10	1	1	1	1	1	1	1	1
	Extended IPI	11	1	1	1	1	1	1	1	0
	User Data	12..N-2	FIS-B							
Frame Check Sequence Field		N-1	fcs_9	fcs_{10}	MOST SIGNIFICANT OCTET				fcs_{15}	fcs_{16}
		N	fcs_1	fcs_2	LEAST SIGNIFICANT OCTET				fcs_7	fcs_8
Flag		N+1	0	1	1	1	1	1	1	0
Reference VDL SARPs, Figure 6-2, VDL Technical Manual Figure 5-1										

3.2.3.2 Services

This section specifies the services offered by the subnetwork sublayer. The services are described in an abstract manner and do not imply any particular implementations. The services provided by the subnetwork to the subnetwork service user shall include the functions described in Sections 3.2.3.2.1 through 3.2.3.2.4.

3.2.3.2.1 Subnetwork Connection Management

A variety of ISO 8208 packet types, procedures, and facilities shall be used to establish, terminate, and manage connections across the subnetwork. Connection status information shall be maintained at both ends of the connection. Connection status information shall also be maximized to ensure that the minimum amount of information is passed with each data transfer phase transmission and that ground system operational control of the subnetwork is maximized.

3.2.3.2.2 Packet Fragmentation and Reassembly

This subnetwork capability shall allow the fragmenting of large data units passed from the subnetwork user for transmission across the A/G portion of the subnetwork. Reassembly shall be performed at the receiving end of the subnetwork.

3.2.3.2.3 Error Recovery

REJECT packet types shall be used for subnetwork-level error recovery. These packets shall be sent between subnetwork entities to cause retransmission of invalid packets and to recover from error response time-out states. Under no circumstances shall RESET or RESTART be used to recover from an error that can be handled by REJECT as described above. Aircraft DTEs shall accept REJECT packets and should retransmit the specified packets.

Note: The ground DCE with which an aircraft has a VDL link should not clear subnetwork connections on receipt of REJECT packets but should retransmit the specified packet(s).

3.2.3.2.4 Connection Flow Control

DATA packet sequence numbering combined with the use of a sliding window shall be used for passive flow control.

Notes:

1. *Receive Not Ready (RNR) packets should not be used for explicit flow control.*

2. *The use of explicit RNRs requires a subsequent packet to clear the f2 (DXE RECEIVE NOT READY) state. The RNRs and subsequent RR frames will cause more RF utilization than*

would be caused by merely delaying the acknowledgment.

3.2.3.3 Packet Format

Except as qualified below, the packet format shall be as specified in ISO 8208, Section 12. During call setup, VDL shall use the extended format in conjunction with the fast select facility.

3.2.3.3.1 General Format Identifier

The Qualifier bit (Q-bit) in DATA packets shall be set to 0 in VDL. Modulo 8 sequencing shall be used in the VDL.

Note: A subnetwork entity may receive a CLEAR CONFIRMATION with the appropriate cause code if the peer subnetwork entity wants to use modulo 128 sequencing.

3.2.3.3.2 Calling and Called DTE Addresses

Calling and called DTE addresses shall be as detailed in Sections 3.2.3.3.2.1 through 3.2.3.3.2.2.3.

3.2.3.3.2.1 Encoding

Octet 5 and consecutive octets shall consist of the called DTE address and the calling DTE address in that order.

3.2.3.3.2.2 Address Field

This variable length field is known informally as the address field. The address field shall be encoded in BCD form. When appropriate, the address field shall be rounded up to an integer number of octets.

3.2.3.3.2.2.1 Aircraft DTE Address

The aircraft DTE address shall be the BCD encoding of the octal representation of the 24-bit ICAO binary address.

3.2.3.3.2.2.2 Ground VDL Specific DTE Addressing (VSDA)

The VDL SARPs supports two addressing options at the subnetwork layer. The default addressing is called VSDA and should be supported by all VDL entities. Optionally, VDL SARPs supports X.121 addressing. The VSDA address consists of six octets. The first three octets of VSDA should be the same as the ATN Administration Domain Identifier (ADM) field as defined in the ATN SARPs. The service provider assigns the second three octets of VSDA. The service provider may use these three octets to uniquely address an air/ground router or may use them as a routing area identifier (same as the ATN Administration Region Selector (ARS) field specified in the ATN SARPs). If the VSDA assigned by the ground service provider does not uniquely identify a specific air/ground router, then the ground system should support X.121 addressing option.

3.2.3.3.2.2.2.1 Ground DTE Address

The VDL subnetwork-specific ground DTE addresses shall be the BCD encoding of the "administration identifier" and optionally the ARS field (from the NET, as defined in the ATN Manual). It shall be sent in the Called Address Extension facility. Bit 8 of the first octet of the facility code shall be set to 1 and bit 7 shall be set to 0. The Called Address shall not be included when using VDL subnetwork-specific ground DTE addresses.

3.2.3.3.2.2.2.2 Ground Network DTE Addresses

If the ground LME indicates support of ground network DTE addresses during link establishment, it shall accept and process addresses which follow the format used in the ground network. All CALL REQUESTs from the ground shall use, as the Calling Address, the ground DTE's X.121 address.

> Note: *This facility allows addressing of ground DTEs other than those associated with the ATN routers in the list of ATN router NETs. It requires, however, that the aircraft system management entity (SME) know or be informed via an application exchange of the address of the DTE in the ground network.*

3.2.3.3.3 Call User Data Field

The fast select facility shall be used to carry VDL mobile SNDCF Call User Data, including the intermediate system hello (ISH) PDU.

> Note: *This reduces the number of transmissions required to set up the various layers. Refer to the ICAO ATN Manual, Chapter 11.*

3.2.3.3.4 Packet Types

Packet encoding shall be as specified in ISO 8208. VDL shall not support the following ISO 8208 packet types: Interrupt, Interrupt Confirmation, and Receiver Not Ready.

3.2.3.4 Subnetwork Layer Service System Parameters

The parameters listed in Table 3-49 shall be used in the subnetwork protocol. Except as noted in Section 3.2.3.6, the description of function and procedures shall be as documented in ISO 8208. For all parameters, Table 3-49 shall indicate the configured or negotiated values that shall be used by the aircraft DTE and the ground DCE. T21, T23, and R23 shall also apply to the ground DTE.

3.2.3.4.1 Packet Size

The Packet Size shall be negotiated via the flow control parameter negotiation facility or Non-standard Default Packet Size facility to be the value in Table 3-49 appropriate to the mode for both directions.

3.2.3.4.2 Parameter W (Transmit Window Size)

The parameter, W, shall be the maximum number of outstanding sequentially numbered data packets that may be transmitted before an acknowledgment is required. In the absence of negotiations via the nonstandard default packet size facility or the flow control parameter negotiation facility, this parameter shall be set per Table 3-49. W shall be negotiated to the same value in both directions.

~~*Note: This parameter is identical to the standard ISO 8208 parameter W.*~~

Table 3-49: Subnetwork Layer Service System Parameter

Symbol	**Name**	**Minimum**	**Maximum**	**VDL Mode 2 Default**
T20	RESTART REQUEST response timer	1 s	300 s	180 s
T21	CALL REQUEST response timer	1 s	300 s	200 s
T22	RESET REQUEST response timer	1 s	300 s	180 s
T23	CLEAR REQUEST response timer	1 s	300 s	180 s
T24	WINDOW STATUS response timer (Optional)	1 s	300 s	180 s
T25	WINDOW ROTATION transmission timer (Optional)	1 s	300 s	180 s
T27	REJECT response timer	1 s	300 s	180 s
R20	RESTART REQUEST retransmission count	0	7	1
R22	RESET REQUEST retransmission count	0	7	1
R23	CLEAR REQUEST retransmission count	0	7	1
P	Packet size	128 octets	2048 octets	1024 octets
W	Transmit window size	1 packet	7 packets	7 packets
A	Acknowledgment window size	1 packet	4 packets	4 packets
LTC	Lowest two-way channel	0	4095	1024
HTC	Highest two-way channel	0	4095	3071

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~~Table 3-49: Subnetwork Layer Service System Parameter~~

~~Symbol~~	~~Name~~	~~Minimum~~	~~Maximum~~	~~VDL Mode 2 Default~~
~~T20~~	~~RESTART REQUEST response timer~~	~~1 s~~	~~300 s~~	~~180 s~~
~~T21~~	~~CALL REQUEST response timer~~	~~1 s~~	~~300 s~~	~~200 s~~
~~T22~~	~~RESET REQUEST response timer~~	~~1 s~~	~~300 s~~	~~180 s~~
~~T23~~	~~CLEAR REQUEST response timer~~	~~1 s~~	~~300 s~~	~~180 s~~
~~T27~~	~~REJECT response timer~~	~~1 s~~	~~300 s~~	~~180 s~~
~~R20~~	~~RESTART REQUEST retransmission count~~	~~0~~	~~7~~	~~1~~
~~R22~~	~~RESET REQUEST retransmission count~~	~~0~~	~~7~~	~~1~~
~~R23~~	~~CLEAR REQUEST retransmission count~~	~~0~~	~~7~~	~~1~~
~~P~~	~~Packet size~~	~~128 octets~~	~~2048 octets~~	~~1024 octets~~
~~W~~	~~Transmit window size~~	~~1 packet~~	~~7 packets~~	~~7 packets~~
~~A~~	~~Acknowledgment window size~~	~~1 packet~~	~~4 packets~~	~~4 packets~~
~~LTC~~	~~Lowest two-way channel~~	~~0~~	~~4095~~	~~1024~~
~~HTC~~	~~Highest two-way channel~~	~~0~~	~~4095~~	~~3071~~

~~*Note: P, W, A values define defaults. Other parameter values are preset and not negotiated. The packet size (P) and window sizes (W,A) define defaults, and may be negotiated during call setup.*~~

Notes: 1. Parameter W is identical to the standard ISO 8208 parameter W.

2. Packet size (P) and Window sizes (W and A) define defaults and may be negotiated during call setup. Other parameter values are preset and are not negotiated.

3.2.3.4.3 Parameter A (Acknowledgment Window Size)

This parameter, A, shall be the minimum number of frames the receiver shall receive before it generates an RR packet. Parameter A shall not be separately negotiated, but shall be set equal to the ceiling of half of W.

> Note: *The purpose of the acknowledgment window is to reduce the probability that an explicit acknowledgment needs to be sent. The acknowledgment window is set to one-half of the transmit window to reduce the probability that a station will go into flow control.*

3.2.3.5 Effects of Layers 1 and 2 on the Subnetwork Layer

The subnetwork layer virtual circuit shall be valid only on the underlying link layer connection over which it was established.

3.2.3.6 Description of Procedures

Except as noted in Sections 3.2.3.6.1 through 3.2.3.6.5, the provisions of ISO 8208 shall apply between the aircraft DTE and the ground DCE. If a ground DCE receives an unsupported packet layer facility, it either shall process the CALL REQUEST without altering the facilities or shall send a CLEAR CONFIRMATION.

3.2.3.6.1 Supported Facilities

Table 3-50 lists options and facilities, documented in ISO 8208, that shall be supported by VDL.

Table 3-50: Facilities Supported By ~~the~~ VDL Mode 2

Facility	ISO 8208 Section
Packet Retransmission	13.4
Reject response timer (T27 timer)	13.4.1
Nonstandard Default Packet Sizes	13.9
Nonstandard Default Window Sizes	13.10
Flow Control Param. Negotiation	13.12
Fast Select	13.16
Fast Select Acceptance	13.17
Called line address modified notification	13.26
Called address extension	14.2

3.2.3.6.2 Unsupported Facilities

Table 3-51 lists the facilities, documented in ISO 8208, that shall not be supported by ~~the~~ VDL Mode 2.

3.2.3.6.3 Subnetwork Establishment and Connection Management

The subnetwork establishment and connection management options used shall be chosen as required by the operational conditions.

Table 3-51: Facilities Not Supported

Facility	ISO 8208 Section
Q-bit	6.6
Non-receipt of window rotation information	11.2
Window status transmission timer (T24 timer)	11.2.2
On line facility registration	13.1
Extended packet sequence numbering	13.2
D-bit modification	13.3
Incoming calls barred	13.5
Outgoing calls barred	13.6
One-way logical channel outgoing	13.7
One-way logical channel incoming	13.8
Default throughput classes assignment	13.11
Throughput class negotiation	13.13
Closed user group related facilities	13.14
Bilateral closed user group related facilities	13.15
Reverse charging	13.18
Reverse charging acceptance	13.19
Local charging prevention	13.20
Network user identification	13.21
Charging information	13.22
RPOA selection	13.23
Hunt group	13.24
Call redirection	13.25
Call redirection notification	13.27
Transit delay selection and indication	13.28
Calling address extension	14.1
Minimum throughput class negotiation	14.3
End-to-end transit delay negotiation	14.4
Expedited data negotiation	14.5

3.2.3.6.3.1 Subnetwork Entity Initialization

The ground DCE shall initialize on receipt of a valid XID_CMD_LE. ~~The aircraft DTE shall initialize on receipt of a valid XID_RSP_LE.~~

Note: Only the subnetwork layer entities corresponding to the link on which the XID_CMD_LE/XID_RSP_LE is received will be initialized. The entities assigned to other links will not be affected.

3.2.3.6.3.2 Subnetwork Connection Establishment

Only aircraft DTEs shall request subnetwork connection establishment in the VDL subnetwork.

3.2.3.6.3.2.1 Explicit Subnetwork Connection Establishment

Immediately after link establishment, the aircraft DTE shall attempt to establish a subnetwork connection to at least one ground DTE. The aircraft DTE shall request a single subnetwork connection per ground DTE by the transmission of a CALL REQUEST packet specifying the ground DTE address in the Called Address field. On receipt of the CALL REQUEST, the ground DCE shall attempt to establish a subnetwork connection to the specified ground DTE. A CALL CONFIRMATION packet shall be sent to the aircraft DTE if the connection is established; otherwise a CLEAR REQUEST packet including a diagnostic specifying the cause of failure shall be sent. The ground DCE shall use the Called Line Address Modified Notification facility to inform the aircraft DTE of the ground DTE's X.121 address if Ground Network DTE addressing is implemented. The ground DCE shall use the Called Address Extension facility to inform the aircraft of the VSDA address if the Ground DTE addressing is implemented.

Note: The Calling Address field in CLEAR CONFIRMATION packet will contain the Aircraft DTE address.

3.2.3.6.3.2.2 Expedited Network Connection Establishment

An aircraft LME initiating expedited network connection establishment shall implement this function. The aircraft LME shall invoke the procedures described in Section 3.2.2.5.4.12 when connecting to a ground LME indicating support for expedited network connection procedures. The aircraft DTE shall reissue CALL REQUESTs for those logical channels for which responses (i.e., either a CALL CONFIRMATION or a CLEAR REQUEST) were not included in the XID_RSP_LE. The ground DCE shall use the Called Line Address Modified Notification facility to inform the aircraft DTE of the ground DTE's X.121 address if Ground Network DTE addressing is implemented. The ground DCE shall use the Called Address Extension facility to inform the aircraft of the VSDA address if the Ground DTE addressing is implemented.

Notes:

1. *The CLEAR CONFIRMATION, if required, will be transferred in an INFO frame.*

2. *The Calling Address field in CLEAR CONFIRMATION packet will contain the Aircraft DTE address.*

3.2.3.6.3.3 Subnetwork Connection Maintenance

During link establishment a ground DCE shall indicate its available routers in the ATN Router NET parameter and the aircraft LME shall then attempt to maintain all subnetwork connections.

Note: *For subnetwork connections to be maintained across ground station changes, the aircraft LME gives preference in choosing a new ground station to ground stations indicating accessibility to the DTEs to which subnetwork connections already exist.*

3.2.3.6.3.3.1 Explicit Subnetwork Connection Maintenance

To explicitly request subnetwork connection maintenance to a ground DTE, an aircraft DTE shall send a CALL REQUEST packet to the ground DTE with a fast select facility containing a VDL mobile SNDCF Call User Data Field indicating a request to maintain SNDCF context.

If the ground DTE can accept the call, it shall respond with a CALL ACCEPTED packet with a fast select facility containing a VDL mobile SNDCF Call User Data field indicating whether the SNDCF context was maintained. If the DTE or a DCE is unable to accept the call, it shall send a CLEAR REQUEST packet to the aircraft DTE including a diagnostic specifying the cause of failure. The ground DTE shall use the Called Line Address Modified Notification facility to inform the aircraft DTE of the ground DTE's X.121 address if Ground Network DTE addressing is implemented. The ground DCE shall use the Called Address Extension facility to inform the aircraft of the VSDA address if the Ground DTE addressing is implemented.

3.2.3.6.3.3.2 Expedited Subnetwork Connection Maintenance

An LME initiating expedited network connection maintenance shall implement this function. If both the aircraft and ground LMEs support expedited subnetwork procedures, then the procedures per Section 3.2.2.5.4.12 shall be invoked. The initiator DTE shall reissue CALL REQUESTs for those logical channels for which responses (i.e., a CALL CONFIRMATION or a CLEAR REQUEST) were not included in the

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XID_RSP_HO. A ground DTE shall set the Calling Address field to its X.121 address. The ground DCE shall use the Called Line Address Modified Notification facility to inform the aircraft DTE of the ground DTE's X.121 address if Ground Network DTE addressing is implemented. The ground DCE shall use the Called Address Extension facility to inform the aircraft of the VSDA address if the Ground DTE addressing is implemented.

> Note: *The CLEAR CONFIRMATION, if required, will be transferred in an INFO frame. How the ground LME obtains the CALL REQUEST packet(s) (in ground-initiated handoffs) is outside the scope of this document.*

3.2.3.6.3.3.3 Broadcast Subnetwork Connection Maintenance

An LME shall set the $b_{\underline{s}}$ bit in the XID AVLC Specific Options parameter to 1 if it supports broadcast subnetwork connections. The procedures per Section 3.2.2.5.4.10 shall be invoked for each aircraft that indicates support for broadcast subnetwork procedures. The ground DTE and DCE and aircraft DTE shall assume those subnetwork connections have been created per Section 3.2.2.5.4.10. If an aircraft DTE cannot accept a call, it shall send a CLEAR REQUEST. If the ground DTE indicated that it maintained the SNDCF context but the aircraft DTE cannot maintain the SNDCF context, it shall send a CALL REQUEST indicating that the SNDCF context is not to be maintained.

> Note: *The CLEAR CONFIRMATION, if required, will be transferred in an INFO frame. How the ground and aircraft LME know how to create the calls with their associated negotiated facilities is outside the scope of this document.*

3.2.3.6.4 Error Handling

An aircraft DTE or ground DCE shall send a CLEAR REQUEST, RESET REQUEST, or RESTART REQUEST packet only for recovery from a DTE failure. When an aircraft DTE or ground DCE receives a packet with a bad sequence number, it shall transmit a REJECT, as specified in ISO 8208, Section 13.4.

3.2.3.6.5 Acknowledgments

An RR packet shall be generated only when a valid DATA packet is received with a P(s), which closes the acknowledgment window. The aircraft DTE or ground DCE shall transmit an RR packet acknowledging the outstanding packets as soon as it is able.

3.2.4 VDL MOBILE SNDCF

3.2.4.1 Introduction

The VDL Mode 2 mobile SNDCF shall be the standard ISO 8208 mobile SNDCF specified in the ICAO Document 9705, except as described below.

3.2.4.2 New Function

The VDL mobile SNDCF shall support maintaining context (e.g., compression tables) across subnetwork calls. The SNDCF shall use the same context (e.g., compression tables) across all SVCs negotiated to a DTE, when negotiated with the same parameters. The SNDCF shall support at least 2 SVCs sharing a context.

> Note: *Because handoffs can be expected to reorder packets, certain compression algorithms do not lend themselves to use over the VDL. Further, implementors of dictionary-based compression algorithms must be sensitive to the problem of updates arriving on either the old or newly established call.*

3.2.4.3 Call User Data Encoding

The Call User Data field shall be as detailed in the ATN Manual, except as modified below.

3.2.4.3.1 ISH PDU

The ISH PDU shall be included in both the CALL REQUEST and CALL CONFIRMATION packets.

3.2.4.3.2 Maintained/Initialized Status Bit

The fifth bit of the compression technique octet (i.e., the sixth octet of the Call User Data field) shall be the Maintained/Initialized (M/I) status bit which is used to indicate whether the SNDCF context (e.g., the compression state) was maintained from an old SVC to a new SVC.

3.2.4.3.3 CALL REQUEST

If the calling SNDCF is requesting that the SNDCF context be maintained from an existing call to the new call being established, it shall set the M/I bit to 1; otherwise, the M/I bit shall be set to 0.

3.2.4.3.4 CALL CONFIRMATION

If the called SNDCF has successfully maintained the entire SNDCF context to the new call being established, it shall set the M/I bit to 1; otherwise, the M/I bit shall be set to 0.

3.3 VDL Mode 3

3.3.1 Physical Layer

The aircraft and ground stations shall access the physical medium operating in simplex mode, as in VDL Mode 2.

3.3.1.1 Functions

The physical layer functions will be the same as for VDL Mode 2 (See Section 3.2.1.1) except that VDL Mode 3 will have an associated voice unit (See Section 3.3.5).

3.3.1.1.1 Transceiver Frequency Control

The VDL physical layer shall set the transceiver (or where physically separate, transmitter and receiver) frequency as commanded by the link management entity (LME).

> Note: *The LME is a Link layer entity specified in Section 3.3.2.3.*

3.3.1.1.2 Data Reception by the Transceiver or Receiver

Signals received by the transceiver or receiver shall be decoded so that they may be accurately read at the higher layers.

3.3.1.1.3 Data Transmission by the Transceiver or Transmitter

The physical layer shall appropriately encode the data received from the VDL Mode 3 data link layer (See Section 3.3.2) and transmit it over the RF channel.

3.3.1.1.4 Notification Services

The notification services shall be the same as for VDL Mode 2 (See Section 3.2.1.1.4).

3.3.1.2 Modulation Scheme

The modulation scheme shall be the same as for VDL Mode 2 (See Section 3.2.1.2).

3.3.1.2.1 Data Encoding

Data encoding shall be the same as for VDL Mode 2 (See Section 3.2.1.2.1).

3.3.1.2.2 Transmitted Signal Form

The transmitted signal form shall be the same as for VDL Mode 2 (See Section 3.2.1.2.2).

3.3.1.2.3 Modulation Rate

Mode 3 shall use the modulation rate and accuracy as specified in Section 3.2.1.2.3.

~~The symbol rate shall be 10,500 symbols/sec, (with a modulation rate accuracy of ± 5 parts per million (ppm) (aircraft only)), resulting in a nominal bit rate of 31,500 bps.~~

~~*Notes:*~~

~~1. *The modulation rate accuracy of the ground system is assumed to be ± 2 ppm.*~~

~~2. *The symbol rate accuracy requirements stated in this section are based on the time maintenance requirements contained in Section 3.3.2.1.4.1 and its subsections. The default values of the coast timer counter thresholds are based on the assumption that the long-term time stabilities of the aircraft and ground radios (in the absence of external time sources) are given by 5 ppm and 2 ppm, respectively. This modulation rate accuracy is much better than is necessary for the demodulation of the information in th VDL Mode 3 bursts. An accuracy on the order of 50 ppm would be sufficient if the demodulation performance were the only criterion for this specification.*~~

3.3.1.2.4 Emission Designator

The emission designator for this modulation technique for TDMA is 14K0G7WET.

14K0 - necessary bandwidth (kHz)
G - Phase modulation
7 - Two or more channels containing quantized or digital signals

W - multi channel system with both telephony and data
E - Multi condition code
T - time division multiplexed

3.3.1.2.5 Pulse Shaping Filters

The requirements for the pulse shaping filters shall be the same as for VDL Mode 2 (See Section 3.2.1.2.5).

3.3.1.3 Time Division Multiple Access (TDMA) Time Slot Bursts

The subsections to this section describe the aspects of the TDMA time slot bursts related to the physical layer. The TDMA Media Access Control (MAC) protocol is defined in Section 3.3.2.1.2. A visual depiction of the TDMA time slot bursts is provided in Figure 3-5.

> *Note: A descriptive example of the correct order in which bits should be transmitted can be found in Appendix F.*

3.3.1.3.1 Management (M) Burst and Handoff Check Message (H) Uplink

The M uplink burst (Section 3.3.2.1.2.1.3) shall consist of three segments, the Training Sequence followed by the System Data, and the Transmitter Ramp Down. The H uplink burst (Section 3.3.2.1.2.1.3) shall consist of three segments, the Training Sequence followed by the Handoff Check Message, and the Transmitter Ramp Down.

3.3.1.3.1.1 Training Sequence

Uplink M burst and H burst training sequences shall consist of two components as follows:

1. Transmitter ramp up and power stabilization
2. Synchronization and ambiguity resolution

3.3.1.3.1.1.1 Transmitter Ramp-Up and Power Stabilization

This shall be as specified in Section 3.2.1.3.1.

3.3.1.3.1.1.2 Synchronization and Ambiguity Resolution

The second component of the uplink training sequence shall consist of the following synchronization sequence known as S_2^* as follows~~:~~

000 001 101 100 110 010 111 100 010 011 101 000 111 000 011 001

and shall be transmitted from left to right.

Note: The sequence S_2^* is very closely related to the sequence S_2 (Section 3.3.1.3.3.1.2). The 15 phase changes between the 16 symbols of S_2^* are each exactly 180° out of phase from the 15 phase changes associated with S_2. This relationship can be used to simplify the process of simultaneously searching for both sequences.

3.3.1.3.1.2 System Data and Handoff Check Message

The non-3T configuration (Section 3.3.2.1.2.4) System Data shall consist of 32 transmitted symbols. The 96 transmitted bits shall include 48 bits of information and 48 parity bits, generated as 4 Golay (24, 12) codewords. The 3T configuration (Section 3.3.2.1.2.4) System Data shall consist of 128 transmitted symbols. The 384 transmitted bits shall include 192 bits of information and 192 parity bits, generated as 16 Golay (24,12) codewords. The 3T configuration Handoff Check Message shall consist of 40 transmitted symbols. The 120 transmitted bits shall include 60 bits of information and 60 parity bits, generated as 5 Golay (24,12) codewords.

The specific definition of the Golay encoder shall be as follows:

If the 12 bit input bit sequence is written as a row vector x, then the 24 bit output sequence can be written as the row vector y, where y = x G, and the matrix G shall be given by~~:~~

(golay encoder)

$$
G = \begin{matrix}
1&1&0&1&0&1&1&1&0&0&0&1&1&0&0&0&0&0&0&0&0&0&0&0\\
0&1&1&1&1&1&0&0&1&0&0&1&0&1&0&0&0&0&0&0&0&0&0&0\\
1&1&1&0&1&0&0&1&0&1&0&1&0&0&1&0&0&0&0&0&0&0&0&0\\
0&1&1&0&0&0&1&1&1&0&1&1&0&0&0&1&0&0&0&0&0&0&0&0\\
1&1&1&0&0&1&1&0&1&1&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
1&0&1&1&0&0&1&1&0&1&1&0&0&0&0&0&0&1&0&0&0&0&0&0\\
1&0&0&1&1&0&0&1&1&0&1&1&0&0&0&0&0&0&1&0&0&0&0&0\\
0&1&0&1&1&0&1&1&1&1&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&1&0&1&1&0&1&1&1&1&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&1&0&1&1&0&1&1&1&1&0&0&0&0&0&0&0&0&0&1&0&0\\
1&1&0&1&1&1&0&0&0&1&1&0&0&0&0&0&0&0&0&0&0&0&1&0\\
1&0&1&0&1&1&1&0&0&0&1&1&0&0&0&0&0&0&0&0&0&0&0&1
\end{matrix}
$$

Note: The extended Golay code allows for correction of any error pattern with three or less bit errors and the detection of any 4-bit error pattern.

3.3.1.3.1.3 Transmitter Ramp-Down

This shall be as specified in Section 3.2.1.3.2.

3.3.1.3.2 Management (M) Burst Downlink

The M downlink burst (Section 3.3.2.1.2.1.3) shall consist of three segments, the Training Sequence followed by the System Data, and the Transmitter Ramp Down.

3.3.1.3.2.1 Training Sequence

The M downlink burst training sequence shall consist of two components as follows:

- Transmitter ramp up and power stabilization
- Synchronization and ambiguity resolution

3.3.1.3.2.1.1 Transmitter Ramp-Up and Power Stabilization

This shall be as defined in Section 3.3.1.3.1.1.1.

3.3.1.3.2.1.2 Synchronization and Ambiguity Resolution

Three separate synchronization sequences shall be used for three M downlink burst types. The standard sequence, known as S_1, shall be ~~as follows:~~

000 111 001 001 010 110 000 011 100 110 011 111 010 101 100 101

and shall be transmitted from left to right.

The special sequence used to identify poll responses, S_2^*, shall be as defined in Section 3.3.1.3.1.1.2.

The special sequence used to identify Net Entry Requests (S_1^*) shall use the ~~following~~ sequence:

000 001 111 111 100 000 110 101 010 000 101 001 100 011 010 011

and shall be transmitted from left to right.

Note: *The sequence S_1^* is very closely related to the sequence S_1. The 15 phase changes between the 16 symbols of S_1^* are each exactly 180° out of phase from the 15 phase changes associated with S_1. This relationship can be used to simplify the process of simultaneously searching for both sequences.*

3.3.1.3.2.2 System Data

The System Data segment shall consist of 16 transmitted symbols. The 48 transmitted bits shall be encoded as 24 bits of System Data and 24 parity bits generated as two consecutive (24, 12) Golay code words.

The encoding of the (24, 12) Golay code words should be as defined in Section 3.3.1.3.1.2.

3.3.1.3.2.3 Transmitter Ramp-Down

This shall be as defined in Section 3.3.1.3.1.3.

3.3.1.3.3 Voice or Data (V/D) Burst

The V/D burst (Section 3.3.2.1.2.1.3) shall consist of four segments: the Training Sequence followed by the Header, the User Information segment, and the Transmitter Ramp Down. The same V/D burst format shall be used for both uplink and downlink.

3.3.1.3.3.1 Training Sequence

V/D burst training sequence shall consist of two components as follows:

- Transmitter ramp-up and power stabilization
- Synchronization and Ambiguity resolution

3.3.1.3.3.1.1 Transmitter Ramp-Up and Power Stabilization

This shall be as specified in Section 3.3.1.3.1.1.1.

3.3.1.3.3.1.2 Synchronization and Ambiguity Resolution

The second component of the V/D burst training sequence shall consist of the following synchronization sequence known as S_2, ~~as follows:~~

000 111 011 010 000 100 001 010 100 101 011 110 001 110 101 111

and shall be transmitted from left to right.

3.3.1.3.3.2 Header

The Header segment shall consist of 8 transmitted symbols. The 24 transmitted bits shall be encoded as 12 bits of Header information and 12 parity bits, generated as a single (24, 12) Golay code word.

The encoding of the (24, 12) Golay code word shall be as defined in Section 3.3.1.3.1.2.

3.3.1.3.3.3 User Information

The User Information segment shall consist of 192 3-bit symbols.

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When transmitting voice, FEC shall be applied to the analysis output of the vocoder as specified in Section 3.3.5.2.1. The vocoder shall provide satisfactory performance in a BER environment of 10^{-3} (with a design goal of 10^{-2}). The overall bit rate of the vocoder *including FEC* is 4800 bps (except when in the truncated mode in which case the bit rate is 4000 bps).

When transmitting user data, the 576 bits shall be encoded as a single Reed-Solomon (72, 62) 2^8-ary code word. For user data input to the Reed-Solomon encoder of length less than 496 bits, input data shall be padded with zeroes at the end to a full length of 496 bits. The field defining the primitive polynomial of the code shall be as described in Section 3.2.1.4.3.1. The generator polynomial for VDL Mode 3 shall be as follows:

$$\prod_{i=120}^{129} (x - \alpha^i)$$

Note: *The Reed-Solomon (72,62) code is capable of correcting five 2^8-ary (codeword) symbol errors in the received word.*

3.3.1.3.3.4 Transmitter Ramp-Down

This shall be as defined in Section 3.3.1.3.1.3.

3.3.1.4 Interleaving

VDL Mode 3 shall not incorporate interleaving.

3.3.1.5 Bit Scrambling

Bit scrambling shall be performed on each burst after the training sequence under VDL Mode 3 operation as specified in Section 3.2.1.6. The scrambling sequence shall be reinitialized on each burst effectively providing a constant overlay for each of the VDL Mode 3 fixed length bursts.

3.3.1.6 Transmit/Receive Turnaround Times

The turnaround times in this subsection are defined as the time between the middle of the last information symbol of one burst and the middle of the first symbol of the *synchronization sequence* of the subsequent burst.

Note: *This nominal time will be shortened by considerations such as the finite width of each symbol due to Nyquist filtering and the ramp up and power stabilization* *sequence. Such alternative definitions could yield switching times up to 8 symbol periods shorter.*

3.3.1.6.1 Receive to Transmit Turnaround Time

An aircraft radio shall be capable of switching from reception to transmission within 17 symbol periods. This time can be relaxed to 33 symbol periods for aircraft radios which do not implement functions requiring discrete addressing.

Notes:

1. *The shortest R/T switching time for an aircraft radio occurs when the reception of an uplink M channel beacon is followed by a V/D transmission in the same slot. In certain instances where aircraft radios do not implement functions requiring discrete addressing, the R/T switching time can be increased since the last two Golay words of the uplink M channel beacon need not be read.*

2. *The minimum turnaround time assumes that in configurations 3V1D, 2V1D, 1V3D, 1V2D, and 3T (see Section 3.3.2.1.2.4) the aircraft radios will be provided with software that will prevent them from transmitting a downlink M channel message in a slot following the reception of a voice message from another aircraft with a long propagation delay.*

   ~~*The minimum turnaround time assumes that in configurations 3V1D, 2V1D, and 3T (see Section 3.3.2.1.2.4) the aircraft radios will be provided with software that will prevent them from transmitting a downlink M channel message in a slot following the reception of a voice message from another aircraft with a long time delay.*~~

3.3.1.6.2 Transmit to Receive Turnaround Time

An aircraft radio shall be capable of switching from transmission to reception within 32 symbol periods.

Note: The worst case T/R switching time for an aircraft radio occurs when it transmits a downlink M-channel message and receives a V/D message in the same slot.

3.3.1.7 Transmission Characteristics

3.3.1.7.1 Carrier Frequencies

VDL Mode 3 has the same requirements for carrier frequencies as VDL Mode 2 (See Section 3.2.1.10.1).

3.3.1.7.2 Spurious Emissions

The spurious emissions requirements are the same as for VDL Mode 2 (See Section 3.2.1.10.2).

3.3.1.7.3 Adjacent Channel Emissions

The requirements for adjacent channel emissions are the same as for VDL Mode 2 (See Section 3.2.1.10.3).

3.3.1.8 Fringe Coverage

3.3.1.8.1 Recommendation

Indication of near edge-of-coverage should be provided to the VDL Mode 3 aircraft user.

3.3.2 Data Link Layer

3.3.2.1 MAC Sublayer (VDL Mode 3)

The MAC sublayer shall support both voice and data operation.

For data operation, the MAC sublayer shall provide for the transparent acquisition of the shared communication path.

For voice operation, the MAC sublayer shall support simplex voice communications with preemptive access for authorized ground users.

3.3.2.1.1 MAC Services

3.3.2.1.1.1 Multiple Access

For data operation, the MAC sublayer shall implement a ground station centralized, reservation-based access to the channel which permits priority-based access. The sublayer shall implement both a polling based access and a random access method for reservation requests.

> Note 1: *These methods provide a fair access (i.e., non-bias) for all aircraft.*

> Note 2: *Uplink data transmission is scheduled directly at the ground station without a reservation request.*

For voice operation, access shall be primarily supported by the user based on a "listen before push–to-talk" discipline. Additionally, authorized ground users shall have the capability to preempt aircraft users occupying the voice channel. Aircraft stations shall not have pre-emption capability.

> Note 3: *This preemptive access provides a limited capability to cope with the "stuck" microphone condition by allowing authorized ground users to deactivate the transmitter of the offending user.*

3.3.2.1.1.1.1 Recommendation

The VDL Mode 3 user should be made aware of a "step-on" condition, i.e. the condition resulting from two VDL Mode 3 users on the same channel attempting to gain access to the channel close enough in time resulting in neither party achieving access.

3.3.2.1.1.2 Channel Occupancy

Channel occupancy is the amount of time a transmitter is allowed to transmit on the channel per *access event.*

For data operation, an access event shall consist of no more than 15 consecutive V/D (data) burst opportunities. For downlink data transmission, an access event shall be the result of a single Reservation Request.

For aircraft voice operation, an access event shall be limited by the duration of the push-to-talk (PTT) assertion or 35 seconds, whichever is less. Voice access shall also honor the voice signaling information issued in the M uplink burst. In case the access event is terminated due to the 35 second limit or because of M uplink burst information, an indication of the termination will be provided for the terminated user (see Section 3.3.2.1.4.2.1).

For ground voice operation, an access event shall be limited by the duration of the PTT assertion.

~~Channel occupancy shall be considered the amount of time spent on the channel *per access event*.~~

~~For data operation, an access event shall consist of no more than 15 consecutive V/D (data) burst opportunities. For downlink data transmission, an access event shall be the result of a single Reservation Request.~~

~~For voice operation, an access event shall not be limited to a fixed number of V/D (voice) burst opportunities. However voice operation shall honor the voice signaling information issued in the M uplink burst. An access event shall correspond with each push-to-talk (PTT) assertion. The maximum duration of a single aircraft radio PTT event shall be limited to 35 seconds. The PTT event shall be automatically terminated and the user being terminated shall be alerted to the termination.~~

3.3.2.1.2 MAC Protocol Framework

3.3.2.1.2.1 Timing Structure

Media access for VDL Mode 3 shall observe the system timing structure described in this section. Observing this timing structure shall be a necessary but not a sufficient condition for media access, as the procedures of Section 3.3.2.1.4 shall also be observed.

3.3.2.1.2.1.1 TDMA Frame

The *TDMA frame* shall be of 120 ms duration and shall contain either 3 or 4 TDMA time slots as determined by the System Configuration (Section 3.3.2.1.2.4) in effect for the ground station. Two consecutive TDMA frames (an even TDMA frame followed by an odd TDMA frame) form a MAC cycle. The concept of MAC cycle is described in Section 3.3.2.1.2.5.

3.3.2.1.2.1.2 Time Slot

A *TDMA time slot* shall be of 30 or 40 ms duration depending on the System Configuration in effect for the ground station. A time slot shall be the basic channel resource allocated to a user group for either voice or data transmission.

Notes:

1. *Multiple time slots can be assigned to a single user group (e.g., voice and data).*

2. *Use of 30 ms slots is considered Normal Range operation; use of 40 ms slots is considered Long Range operation.*

3.3.2.1.2.1.2.1 Timing Accuracy (Timing State 1)

While in Timing State 1 (see Section 3.3.2.1.4.1.4) an aircraft radio's slot timing error shall be less than 1 symbol period.

Note: The correct slot timing for an aircraft radio in TS1 is equal to that of its associated ground station plus an offset equal to the ground-to-air propagation time.

3.3.2.1.2.1.2.2 Timing Accuracy (Timing State 2 or 3)

While in Timing State 2 or 3 (see Section 3.3.2.1.4.1.4) an aircraft radio's slot timing shall drift at a rate no greater than ±5 ppm.

Note: This drift rate, in conjunction with an assumed maximum drift rate of ±2 ppm for a ground station, provides the rationale for the timing rules specified in Section 3.3.2.1.4.1.

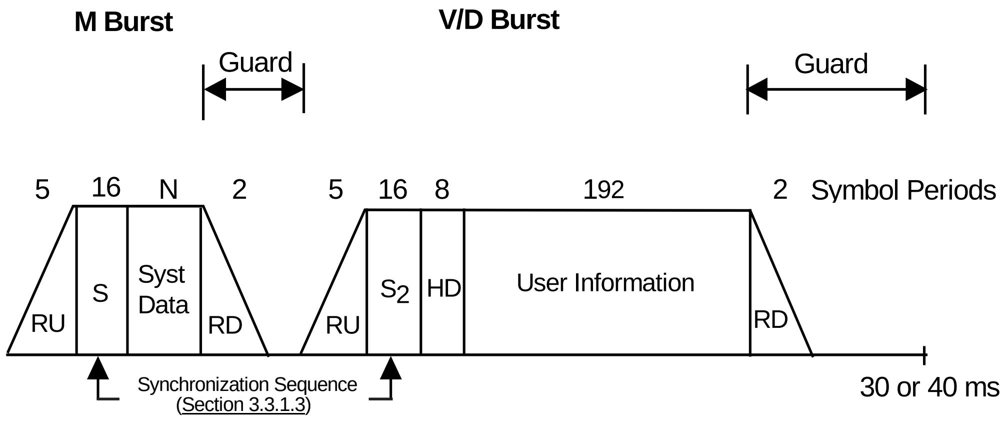
3.3.2.1.2.1.3 Bursts

A TDMA time slot shall consist of either a) one Management (M) burst and one Voice or Data (V/D) burst, b) four M bursts, or c) one M burst and one handoff check message (H) burst. The format of the bursts shall be as specified in Figures 3-5a, 3-5b, and 3-5c. Figure 3-5a shows a typical time slot to consist of an M burst followed by a V/D burst. Figure 3-5b shows slot A of a 3T configuration downlink to consist of four management M bursts. Figure 3-5c shows slot A of a 3T configuration uplink to consist of a management burst and an H burst.

Note~~s~~:

1. *An M burst is used for signaling and link management. A V/D burst is used for user information. An H burst is used to facilitate automated handoff of ground stations.*

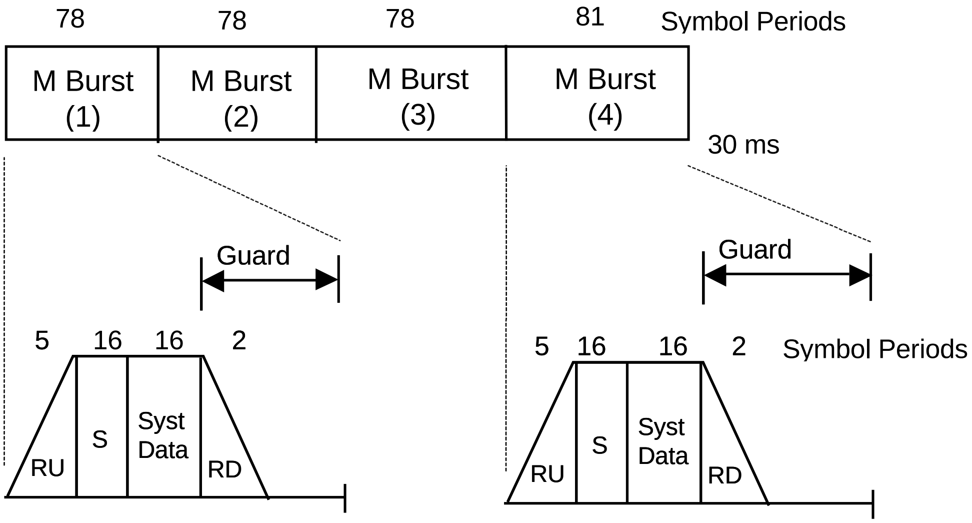
~~*2.These diagrams show rectangular symbol periods for reasons of clarity. In practice each symbol lasts a total of 5 symbol periods, and is best identified by its center point (where its magnitude is a maximum, and all others are of zero magnitude). The centers of the actual symbols can be considered to be coincident with the center of the rectangular symbols in the simplified representation.*~~


M Burst
V/D Burst
Guard
Guard
5
16
N
2
5
16
8
192
2
Symbol Periods
RU
S
Syst Data
RD
RU
S_2
HD
User Information
RD
Synchronization Sequence (Section 3.3.1.3)
30 or 40 ms

RU: Ramp-up and power stabilization
RD: Ramp-down
HD: Header

S = S_2* for uplink (Section 3.3.1.3.1.1.2);
S_1, S_2*, or S_1* for downlink (Sections 3.3.1.3.1.1.2 and 3.3.1.3.2.1.2)
N = 32 for uplink; 16 for downlink

Figure 3-5a: **Management (M) and V/D Bursts and Slot Components**


78
78
78
81
Symbol Periods
M Burst (1)
M Burst (2)
M Burst (3)
M Burst (4)
30 ms
Guard
Guard
5
16
16
2
5
16
16
2
Symbol Periods
RU
S
Syst Data
RD
RU
S
Syst Data
RD

[Also for M(2) and M(3)]

RU: Ramp-up and power stabilization
RD: Ramp-down

S = S_1 or S_1* for M(1) (Section 3.3.1.3.2.1.2);
S_1, S_2*, or S_1* for M(2), M(3), and M(4) (Sections 3.3.1.3.1.1.2 and 3.3.1.3.2.1.2)

Figure 3-5b: **Four Management (M) Bursts and Slot Components (Downlink Slot A of 3T)**

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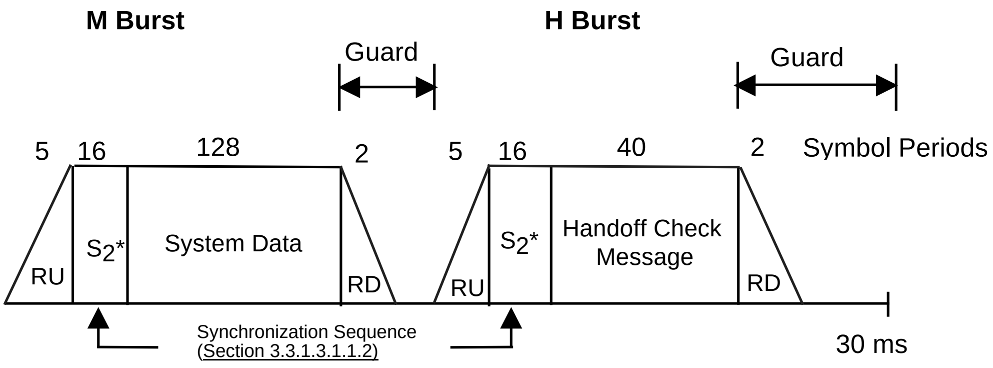


RU: Ramp-up and power stabilization
RD: Ramp-down

Figure 3-5c: Bursts and Slot Components for Management (M) and Handoff Check Message (H) Bursts (Uplink Slot A of 3T)

The time scale hierarchy for TDMA frames, time slots and bursts shall be as shown in Figures 3-6a, 3-6b, and 3-6c. Figure 3-6a shows the TDMA frame structure of a normal range non-3T configuration. Figure 3-6b shows the TDMA frame structure of a normal range 3T configuration. Figure 3-6c shows the TDMA frame structure for long range configurations.

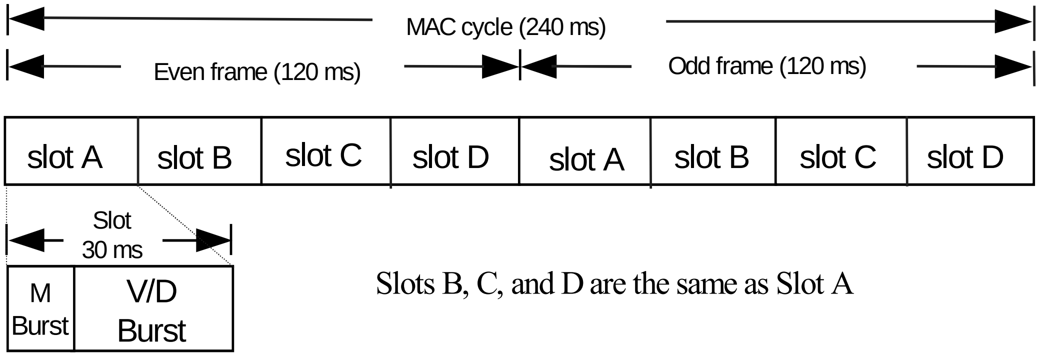
> Note: *The only difference in the timing structure between the Normal Range 30 ms slots and the Long Range 40 ms slots is an increased propagation guard time allowance. The exact allocation of propagation guard time is reflected in Tables 3-54, 3-55, and 3-56.*

3.3.2.1.2.1.4 Epoch

An Epoch shall consist of 25 MAC cycles (6 seconds). MAC cycle is defined in Section 3.3.2.1.2.5. Epochs shall begin at the following number of seconds after the minute: 0, 6, 12, 18, 24, 30, 36, 42, 48, 54.

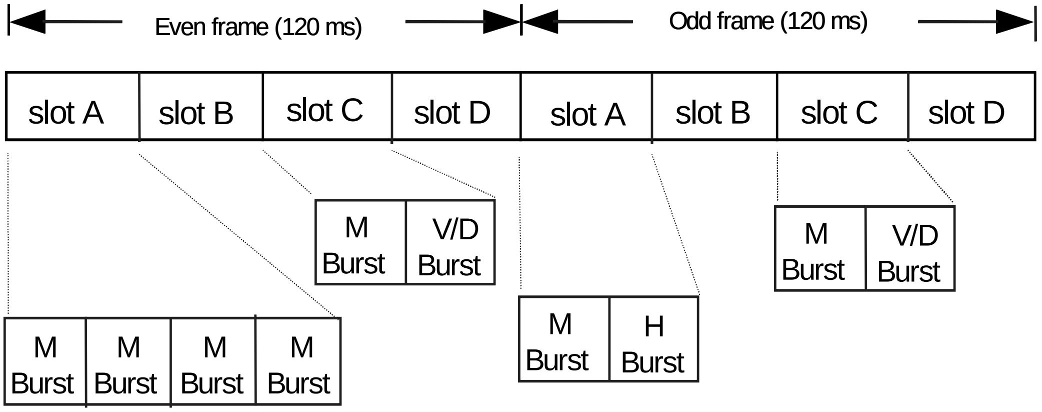
3.3.2.1.2.1.5 External Time Reference Interface

VDL Mode 3 ground stations shall synchronize their station TDMA system timing clocks to a common absolute time standard. ~~The VDL Mode 3 ground stations shall have the option to synchronize their station TDMA system timing clocks to a common absolute time standard.~~ This external time source shall provide a timing strobe once per second on the second and a means to identify epoch boundaries. For the purpose of providing epoch strobes, the external time source shall be aligned to UTC on 6 January 1980.


MAC cycle (240 ms)
Even frame (120 ms)
Odd frame (120 ms)
slot A
slot B
slot C
slot D
slot A
slot B
slot C
slot D
Slot
30 ms
M
Burst
V/D
Burst

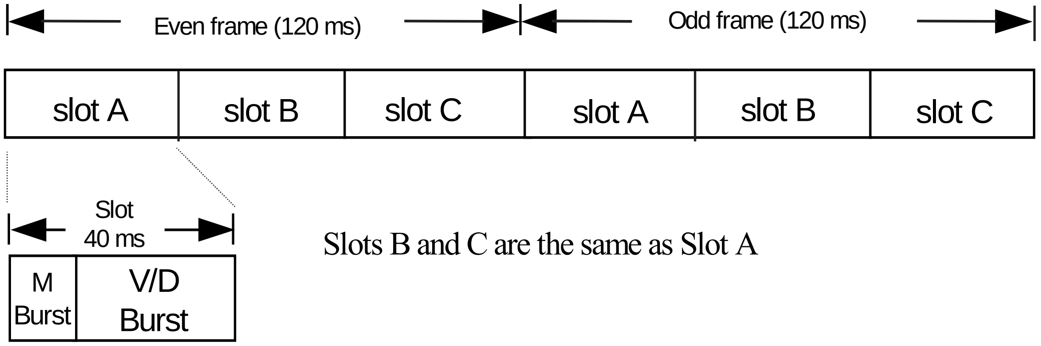
Slots B, C, and D are the same as Slot A

Figure 3-6a: Frame Structure for Normal Range Non-3T Configurations (Section 3.3.2.1.2.3)


Even frame (120 ms)
Odd frame (120 ms)
slot A
slot B
slot C
slot D
slot A
slot B
slot C
slot D
M
Burst
V/D
Burst
M
Burst
M
Burst
M
Burst
M
Burst
M
Burst
H
Burst
M
Burst
V/D
Burst

Slots B and D are the same as Slot C

Figure 3-6b: Frame structure for Normal Range 3T Configurations (Section 3.3.2.1.2.3)


Even frame (120 ms)
Odd frame (120 ms)
slot A
slot B
slot C
slot A
slot B
slot C
Slot
40 ms
M
Burst
V/D
Burst

Slots B and C are the same as Slot A

Figure 3-6c: Frame Structure for Long Range Configurations (Section 3.3.2.1.2.3)

Notes:

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1. *UTC is not easily usable as a time source for VDL Mode 3 because UTC requires leap second adjustments at irregular intervals.*

2. *GPS system time was aligned to UTC time on 6 January 1980, but now differs by an integral number of seconds. (A GPS receiver calculates GPS system time and provides conversion to UTC time by adding the appropriate number of leap seconds. This number is available as a part of the GPS navigational message.) Any other absolute time source which is traceable to UTC without leap second adjustments is also suitable as an external time source for VDL Mode 3.*

2. *Synchronization of aircraft radios to a common external time source is not required for VDL Mode 3 operation.*

3.3.2.1.2.2 System Data and Header Field Formats

Fields contained in the System Data segment of the M uplink bursts and the Header segment of the V/D bursts shall be used for controlling access to the channel and for link management functions (Section 3.3.2.3). The definition of the fields of these burst segments shall be as given in Appendix G.

3.3.2.1.2.3 User Groups

An aircraft radio shall be associated with a *user group* for purposes of channel access for voice and data transmissions and for aircraft addressing functions used by the ground station. A single ~~VDL~~ frequency assignment for VDL Mode 3 shall support from one to four user groups depending on the System Configuration in effect for that ground station.

3.3.2.1.2.4 System Configurations

VDL Mode 3 equipment shall recognize and support the set of system configurations identified in Table 3-52, with the exception of the optional 3T configuration.

Note: See Section 1.3.4 for the description of each system configuration.

~~VDL Mode 3 shall recognize and support the set of system configurations identified in Table 3-52.~~

~~*Note: Reference the ICAO VDL Mode 3 Implementation Aspects for the applications and descriptions of each system configuration.*~~

Table 3-52: System Configurations

	System Configuration	User Groups Supported /Identifying Time Slots*	Services to Each Group	V/D Slots Assigned to Each Group
Normal Range	4V	4/(A, B, C, D)	Dedicated voice circuit	A, B, C, or D
	3V1D	3/(A, B, C)	Dedicated voice circuit w/shared data circuit	A/D, B/D, or C/D
	2V2D	2/(A, B)	Dedicated voice circuit w/dedicated data circuit	A/C or B/D
	3T	1/(A)	Demand assigned voice and data	B/C/D
	1V3D	1/(A,B,C,D)	Dedicated voice circuit w/ dedicated data circuit	A/B/C/D
Long Range	3V	3/(A, B, C)	Dedicated voice circuit	A, B, or C
	3S	1/(A, B, C)	Dedicated voice circuit with 3 station diversity	A/B/C
	2S1X	1/(A,C)	Dedicated voice circuit with 2 station diversity	A/C
	2V1D	2/(A, B)	Dedicated voice circuit w/shared data circuit	A/C or B/C
	1V2D	1/(A,B,C)	Dedicated voice circuit w/ dedicated data circuit	A/B/C

	~~System Configuration~~	~~User Groups Supported /Identifying Time Slots*~~	~~Services to Each Group~~	~~V/D Slots Assigned to Each Group~~
~~Normal Range~~	~~4V~~	~~4/(A, B, C, D)~~	~~Dedicated voice circuit~~	~~A, B, C, or D~~
	~~3V1D~~	~~3/(A, B, C)~~	~~Dedicated voice circuit w/shared data circuit~~	~~A/D, B/D, or C/D~~
	~~2V2D~~	~~2/(A, B)~~	~~Dedicated voice circuit w/dedicated data circuit~~	~~A/C or B/D~~
	~~3T~~	~~1/(A)~~	~~Demand assigned voice and data~~	~~B/C/D~~

~~Long Range~~	~~3V~~	~~3/(A, B, C)~~	~~Dedicated voice circuit~~	~~A, B, or C~~
	~~3S~~	~~1/(A, B, C)~~	~~Dedicated voice circuit with 3 station diversity~~	~~A/B/C~~
	~~2S1X~~	~~1/(A,C)~~	~~Dedicated voice circuit with 2 station diversity~~	~~A/C~~
	~~2V1D~~	~~2/(A, B)~~	~~Dedicated voice circuit w/shared data circuit~~	~~A/C or B/C~~

** The term "identifying time slots" is defined as the value in the Slot Number field in the Beacon2 word of the uplink M ~~channel~~burst.*

3.3.2.1.2.5 Media Access Control Cycle

Media access shall be based on a *MAC cycle* of 240 ms (two consecutive TDMA frames, denoted even and odd frames, per Figure 3-6).

Note: MAC cycles for each System Configuration are shown in the ICAO VDL Mode 3 Implementation Aspects.

3.3.2.1.2.5.1 Logical Burst Access Channels

For configurations 4V, 2V2D, 3V, 3V1D, and 2V1D, VDL shall grant media access individually for each of up to 8 separate LBACs numbered 1 - 8. A description of each LBAC for these cases shall be as given in Table 3-53. For the 3T configuration, VDL shall grant media access individually for each of up to 18 separate Logical Burst Access Channels (LBACs) numbered 1-18. A description of each LBAC for the 3T configuration is given in Table 3-55. For the 3S configuration, VDL shall grant media access individually for each of up to 10 separate LBACs numbered 1-10. A description of each LBAC for the 3S configuration is given in Table 3-56a. For the 2S1X configuration, VDL shall grant media access individually for each of up to 7 separate LBACs numbered 1 - 7. A description of each LBAC for the 2S1X configuration is given in Table 3-56b. For the 1V3D configuration, VDL shall grant media access individually for each of up to 16 separate LBACs numbered 1-16. A description of each LBAC is given in Table 3-56c. For the 1V2D configuration, VDL shall grant media access individually for each of up to 12 separate LBACs numbered 1-12. A description of each LBAC is given in Table 3-56d.

Note: MAC cycles for most System Configurations are shown labeled with each LBAC in the ICAO VDL Mode 3 Implementation Aspects.

~~For all configurations (except 3T, 3S, and 2S1X), VDL shall grant media access individually for each of up to 8 separate LBACs numbered 1 - 8. A description of each LBAC for these cases (other than 3T, 3S, and 2S1X) shall be as given in Table 3-53. For the 3T configuration, VDL shall grant media access individually for each of up to 18 separate Logical Burst Access Channels (LBACs) numbered 1-18. A description~~

~~of each LBAC for the 3T configuration is given in Table 3-55. For the 3S configuration, VDL shall grant media access individually for each of up to 10 separate LBACs numbered 1-10. A description of each LBAC for the 3S configuration is given in Table 3-56a. For the 2S1X configuration, VDL shall grant media access individually for each of up to 7 separate LBACs numbered 1 - 7. A description of each LBAC for the 2S1X configuration is given in Table 3-56b.~~

~~*Note: MAC cycles for each System Configuration are shown labeled with each LBAC in the ICAO VDL Mode 3 Implementation Aspects.*~~

Table 3-53: Logical Burst Access Channel (LBAC) Descriptions for Configurations
4V, 2V2D, 3V, 3V1D and 2V1D.
~~Other Than 3T, 3S, and 2S1X~~

LBAC# *	Applicability	Description
1	air only	M downlink burst used for poll response or Random Access (RA)
2	air, ground	V/D (voice) burst even TDMA frame
3	air only	M downlink burst used for ACK or RA even TDMA frame
4	air, ground	V/D (data) burst even TDMA frame
5	ground only	M uplink burst and timing reference point
6	air, ground	V/D (voice) burst odd TDMA frame
7	air only	M downlink burst used for ACK or RA odd TDMA frame
8	air, ground	V/D (data) burst odd TDMA frame

~~LBAC# *~~	~~Applicability~~	~~Description~~
~~1~~	~~air only~~	~~M downlink burst used for poll response or Random Access (RA)~~
~~2~~	~~air, ground~~	~~V/D (voice) burst even TDMA frame~~
~~3~~	~~air only~~	~~M downlink burst used for ACK or RA even TDMA frame~~
~~4~~	~~air, ground~~	~~V/D (data) burst even TDMA frame~~
~~5~~	~~ground only~~	~~M uplink burst and timing reference point~~
~~6~~	~~air, ground~~	~~V/D (voice) burst odd TDMA frame~~
~~7~~	~~air only~~	~~M downlink burst used for ACK or RA odd TDMA frame~~
~~8~~	~~air, ground~~	~~V/D (data) burst odd TDMA frame~~

* Used to identify burst opportunities in Table 3-54.

Note: For 4V and 3V only LBACs 1, 2, 5, and 6 apply, as shown in Table 3-54.

3.3.2.1.2.5.2 Burst Access Timing

The System Configuration code provided in the M uplink burst (Appendix G, Section G.2.1) shall be used by the aircraft station in conjunction with the timing reference point (TRP) to establish proper burst timing. For configurations 4V, 2V2D, 3V, 3V1D, and 2V1D, LBACs shall be established according to Table 3-54; for the 3T configuration, LBACs shall be established according to Table 3-55; for the 3S configuration, LBACs shall be established according to Table 3-56a; for the 2S1X configuration, LBACs shall be established according to Table 3-56b; for the 1V3D configuration, LBACs shall be established according to Table 3-56c; and for the 1V2D configuration, LBACs shall be established according to Table 3-56d.” The TRP shall be established per Section 3.3.2.1.4.1. The relative timings among the TRPs of different user groups for the various system configurations are shown in Table 3-56e.

~~The System Configuration code provided in the M uplink burst (Appendix G, Section G.2.1) shall be used by the aircraft VDL in conjunction with the timing reference point (TRP) to establish proper burst timing. For all configurations (except 3T, 3S, and 2S1X), LBACs shall be established according to Table 3-54; for the 3T configuration, LBACs shall be established according to Table 3-55; for the 3S configuration, LBACs shall be established according to Table 3-56a; and for the 2S1X configuration, LBACs shall be established according to Table 3-56b. The TRP shall be established per Section 3.3.2.1.4.1. The relative timings among the the TRPs of different user groups for the various system configurations are shown in Table 3-56c.~~

Table 3-54: LBAC Timing Offset Values for Configurations 2V2D, 3V, 3V1D and 2V1D.~~Other Than 3T, 3S, and 2S1X~~

System Config.	User Group Slot ID	Media Access Timing for Each LBAC (See Section 3.3.2.1.2.5.1) Relative to Timing Reference Point (Symbol Periods)							
		Even Frame				Odd Frame			
		1	2	3	4	5	6	7	8
4 Slots Per Frame (Normal Range)									
4V	A-D	-1260	-1195	N/A	N/A	0	65	N/A	N/A
3V1D	A	-1260	-1195	-315	-250	0	65	945	1010
	B	-1260	-1195	-630	-565	0	65	630	695
	C	-1260	-1195	-945	-880	0	65	315	380
2V2D	A-B	-1260	-1195	-630	-565	0	65	630	695
3 Slots Per Frame (Long Range)									
3V	A-C	-1260	-1142	N/A	N/A	0	118	N/A	N/A
2V1D	A	-1260	-1142	-420	-302	0	118	840	958
	B	-1260	-1142	-840	-722	0	118	420	538

3.3.2.1.2.5.3 Access Rules for M Downlink

Use of M downlink is either via dedicated access or random access (RA). Use of M downlink for transmitting Poll Response, Next Net Acknowledgement, and downlink ACK messages is by dedicated access. Use of M downlink for transmitting Reservation Request, Net Entry, and Leave Net messages is in accordance with the Slotted Aloha random access algorithm discussed in Appendix I. The rules for determining whether a particular LBAC channel, which is associated with M Downlink, is available for RA or dedicated access shall be as shown in Table 3-57.

3.3.2.1.3 Aircraft MAC Service System Parameters

Aircraft MAC service system parameters shall be as defined in Table 3-58a and Table 3-58b. Descriptions of the parameters are provided in Sections 3.3.2.1.3.1 through 3.3.2.1.3.7.

Table 3-55: LBAC Description and Timing for 3T Configuration

LBAC#	Applicability	Description	Media Access Timing for Each LBAC Relative to Timing Reference Point (Symbol Periods)
1	air only	M downlink RA	-1260
2	air only	M downlink poll response or RA	-1182
3	air only	M downlink pollresponse or RA	-1104
4	air only	M downlink poll response or RA	-1026
5	air only	M downlink ACK or RA	-945
6	air/ground	V/D even frame (D only)	-880
7	air only	M downlink ACK or RA	-630
8	air/ground	V/D even frame (D only)	-565
9	air only	M downlink ACK or RA	-315
10	air/ground	V/D even frame (V or D)	-250
11	ground only	M uplink, Timing Reference Point	0
12	ground only	M uplink handoff check	201
13	air only	M downlink ACK or RA	315
14	air/ground	V/D odd frame (D only)	380
15	air only	M downlink ACK or RA	630
16	air/ground	V/D odd frame (D only)	695
17	air only	M downlink ACK or RA	945
18	air/ground	V/D odd frame (V or D)	1010

Note: *Reference the ICAO VDL Mode 3 Implementation Aspects for further description of 3T Timing.*

Table 3-56a: LBAC Description and Timing for 3S Configuration

LBAC #	Applicability	Description	Media Access Timing for Each LBAC Relative to Timing Reference Point (Symbol Periods)
1	Air only	M downlink poll response or RA	-1260
2	Air, Ground	V/D (voice) even frame	-1142
3	Ground only	V/D (voice) even frame	-722
4	Ground only	V/D (voice) even frame	-302
5	Ground only	M uplink and timing reference point	0
6	Air, Ground	V/D (voice) odd frame	118
7	Ground only	M uplink and timing reference point	420
8	Ground only	V/D (voice) odd frame	538
9	Ground only	M uplink and timing reference point	840
10	Ground only	V/D (voice) odd frame	958

Table 3-56b: LBAC Description and Timing for 2S1X Portion of Configuration

LBAC #	Applicability	Description	Media Access Timing for Each LBAC Relative to Timing Reference Point (Symbol Periods)
1	Air only	M downlink poll response or RA	-1260
2	Air, Ground	V/D (voice) even frame	-1142
3	Ground only	V/D (voice) even frame	-302
4	Ground only	M uplink and timing reference point	0
5	Air, Ground	V/D (voice) odd frame	118
6	Ground only	M uplink and timing reference point	840
7	Ground only	V/D (voice) odd frame	958

Table 3-56c: LBAC Description and Timing for 1V3D Configuration

LBAC #	APPLICABILITY	**Description**	**Media Access Timing for Each LBAC Relative to Timing Reference Point (Symbol Periods)**
1	Air only	M downlink poll response	-1260
2	Air/Ground	V/D (voice) even frame	-1195
3	Air only	M downlink ACK or RA	-945
4	Air/Ground	V/D (data) even frame	-880
5	Air only	M downlink ACK or RA	-630
6	Air/Ground	V/D (data) even frame	-565
7	Air only	M downlink ACK or RA	-315
8	Air/Ground	V/D (data) even frame	-250
9	Ground only	M uplink, Timing Reference Point	0
10	Air/Ground	V/D (voice) odd frame	65
11	Air only	M downlink ACK or RA	315
12	Air/Ground	V/D (data) odd frame	380
13	Air only	M downlink ACK or RA	630
14	Air/Ground	V/D (data) odd frame	695
15	Air only	M downlink ACK or RA	945
16	Air/Ground	V/D (data) odd frame	1010

Table 3-56d: LBAC Description and Timing for 1V2D Configuration

LBAC #	APPLICABILITY	**Description**	**Media Access Timing for Each LBAC Relative to Timing Reference Point (Symbol Periods)**
1	Air only	M downlink poll response	-1260
2	Air/Ground	V/D (voice) even frame	-1142
3	Air only	M downlink ACK or RA	-840
4	Air/Ground	V/D (data) even frame	-722
5	Air only	M downlink ACK or RA	-420
6	Air/Ground	V/D (data) even frame	-302
7	Ground only	M uplink, Timing Reference Point	0
8	Air/Ground	V/D (voice) even frame	118

9	Air only	M downlink ACK or RA	420	
10	Air/Ground	V/D (data) odd frame	538	
11	Air only	M downlink ACK or RA	840	
12	Air/Ground	V/D (data) odd frame	958	

Table 3-56e~~e~~: Relative Timing Relationship for TRPs of Different User Groups for All System Configurations

	Relative Timings Among TRPs of Different User Groups (Symbol Periods)									
User Group ID	**4V**	**3V1D**	**2V2D**	**3T***	**3V**	**3S****	**2S1X*****	**2V1D**	1V3D****	1V2D****
A	0	0	0	N/A	0	0	0	0	0	0
B	315	315	315	0	420	420	N/A	420	0	0
C	630	630	N/A	0	840	840	840	N/A	0	0
D	945	N/A	N/A	0	N/A	N/A	N/A	N/A	0	0

* For 3T configuration, Group IDs B, C, and D are treated as one user group.
** For 3S configuration, Group IDs A, B, and C are treated as one user group.
*** For 2S1X configuration, Group IDs A and C are treated as one user group.
**** For 1V3D and 1V2D configurations, Group IDs A, B, C, and D are treated as one user group.

	~~Relative Timings Among TRPs of Different User Groups (Symbol Periods)~~							
~~**User Group ID**~~	~~**4V**~~	~~**3V1D**~~	~~**2V2D**~~	~~**3T***~~	~~**3V**~~	~~**3S****~~	~~**2S1X*****~~	~~**2V1D**~~
~~A~~	~~0~~	~~0~~	~~0~~	~~N/A~~	~~0~~	~~0~~	~~0~~	~~0~~
~~B~~	~~315~~	~~315~~	~~315~~	~~0~~	~~420~~	~~420~~	~~N/A~~	~~420~~
~~C~~	~~630~~	~~630~~	~~N/A~~	~~0~~	~~840~~	~~840~~	~~840~~	~~N/A~~
~~D~~	~~945~~	~~N/A~~	~~N/A~~	~~0~~	~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~

~~* For 3T configuration, Group IDs B, C, and D are treated as one user group.~~
~~** For 3S configuration, Group IDs A, B, and C are treated as one user group.~~
~~*** For 2S1X configuration, Group IDs A and C are treated as one user group.~~

3.3.2.1.3.1 Parameter t (Truncation)

This parameter shall be the number of MAC cycles which can elapse in normal timing state 1 (TS1) while not receiving a primary time reference (defined in Section 3.3.2.1.4.1.1) without requiring transmitted V/D (voice) bursts to be truncated.

Note: *This parameter is determined by the symbol clock stability of the aircraft VDL and represents the number of MAC cycles prior to accumulating a timing drift of ±1 symbol periods.*

Table 3-57: Access Rules for M Downlink

Configuration	LBAC #	Utilization of LBAC	
		RA	ACK
4V, 2V2D, 3V, 3V1D and 2V1D~~Other than 3T, 3S, and 2S1X~~	1	LBAC 5 in previous MAC cycle did not request a poll response	No acknowledgement allowed
	3	LBAC 4 in previous MAC cycle did not have an uplink V/D (data) burst Header segment with EOM* = 1	LBAC 4 in previous MAC cycle had an uplink V/D (data) burst Header segment with EOM = 1
	7	LBAC 8 in previous MAC cycle did not have an uplink V/D (data) burst Header segment with EOM = 1	LBAC 8 in previous MAC cycle had an uplink V/D (data) burst Header segment with EOM = 1
3T	1	Unconditional RA	No acknowledgement allowed
	2	LBAC 11 in previous MAC cycle did not request a poll response	No acknowledgement allowed
	3	LBAC 11 in previous MAC cycle did not request a poll response	No acknowledgement allowed
	4	LBAC 11 in previous MAC cycle did not request a poll response	No acknowledgement allowed
	5	LBAC 6 in previous MAC cycle did not have an uplink V/D (data) burst Header segment with EOM = 1	LBAC 6 in previous MAC cycle had an uplink V/D (data) burst Header segment with EOM = 1
	7	LBAC 8 in previous MAC cycle did not have an uplink V/D (data) burst Header segment with EOM = 1	LBAC 8 in previous MAC cycle had an uplink V/D (data) burst Header segment with EOM = 1
	9	LBAC 10 in previous MAC cycle did not have an uplink V/D (data) burst Header segment with EOM = 1	LBAC 10 in previous MAC cycle had an uplink V/D (data) burst Header segment with EOM = 1
	13	LBAC 14 in previous MAC cycle did not have an uplink V/D (data) burst Header segment with EOM = 1	LBAC 14 in previous MAC cycle had an uplink V/D (data) burst Header segment with EOM = 1
	15	LBAC 16 in previous MAC cycle did not have an uplink V/D (data) burst Header segment with EOM = 1	LBAC 16 in previous MAC cycle had an uplink V/D (data) burst Header segment with EOM = 1
	17	LBAC 18 in previous MAC cycle did not have an uplink V/D (data) burst Header segment with EOM = 1	LBAC 18 in previous MAC cycle had an uplink V/D (data) burst Header segment with EOM = 1
3S	1	LBAC 5, 7, or 9 in previous MAC cycle did not request a poll response	No acknowledgement allowed
2S1X	1	LBAC 4 or 6 in previous cycle did not request a poll response	No acknowledgement allowed.
1V3D	1	N/A (Poll Response only)	No acknowledgment allowed
	3	LBAC 4 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 4 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1
	5	LBAC 6 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 6 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1
	7	LBAC 8 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 8 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1

	11	LBAC 12 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 12 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1
	13	LBAC 14 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 14 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1
	15	LBAC 16 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 16 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1
1V2D	1	N/A (Poll Response only)	No acknowledgment allowed
	3	LBAC 4 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 4 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1
	5	LBAC 6 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 6 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1
	9	LBAC 10 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 10 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1
	11	LBAC 12 in previous MAC cycle did not have an uplink V/D (data) burst header with EOM=1	LBAC 12 in previous MAC cycle had an uplink V/D (data) burst header with EOM=1

* Defined in Section G.3.1.2 of Appendix G.

Table 3-58a: Aircraft MAC Service System Parameters

Symbol	Parameter Name	Min.	Max.	VDL Mode 3 Default	Increment
t	Truncation (MAC cycles)	1	256	50*	1
f	Free Running (MAC Cycles)	1	256	250*	1
NM1	Maximum Retry	1	128	20	1
RE	Net Entry Randomizer	1	256	**	1
RR	Reservation Request Randomizer	1	256	**	1
RL	Leaving Net Randomizer	1	256	**	1
WR	Reservation Request Delay (MAC Cycle)	1	256	**	1

* Based on the specified clock accuracy of 5 ppm for aircraft radios and 2 ppm for ground radios plus 1 ppm timing shift due to a Mach 1 aircraft.

** Value depends upon system configurations and is defined in Table 3-58b.

~~Table 3-58b: Aircraft MAC Service System Parameters~~

		~~System Configuration~~							
~~Symbol~~	~~Parameter Name~~	~~4V~~	~~3V1D~~	~~2V2D~~	~~3T~~	~~3V~~	~~2V1D~~	~~3S~~	~~2S1X~~
~~RE~~	~~Net Entry Randomizer~~	~~3~~	~~8~~	~~8~~	~~8~~	~~3~~	~~8~~	~~3~~	~~3~~
~~RR~~	~~Reservation Request Randomizer~~	~~3~~	~~8~~	~~8~~	~~8~~	~~3~~	~~8~~	~~3~~	~~3~~
~~RL~~	~~Leaving Net Randomizer~~	~~3~~	~~8~~	~~8~~	~~8~~	~~3~~	~~8~~	~~3~~	~~3~~
~~WR~~	~~Reservation Request Delay (MAC cycle)~~	~~1~~	~~2~~	~~2~~	~~2~~	~~1~~	~~2~~	~~1~~	~~1~~

~~Notes: 1. Parameters RE, RR, RL, and WR are system configuration dependent.~~

~~2. Units for RE, RR, RL are in number of available time slots.~~

Table 3-58b: Aircraft MAC Service System Parameters

		System Configuration									
Symbol	Parameter Name	4V	3V1D	2V2D	3T	3V	2V1D	3S	2S1X	1V3D	1V2D
RE	Net Entry Randomizer (Note 2)	3	8	8	8	3	8	3	3	8	8
RR	Reservation Request Randomizer (Note 2)	3	8	8	8	3	8	3	3	8	8
RL	Leaving Net Randomizer (Note 2)	3	8	8	8	3	8	3	3	8	8
WR	Reservation Request Delay (MAC cycle)	1	2	2	2	1	2	1	1	2	2

Notes: 1. Parameters RE, RR, RL, and WR are system configuration dependent.
2. Units for RE, RR, RL are in number of available time slots.

3.3.2.1.3.1.1 Validity Window

A timing beacon (with appropriate Slot ID and Ground Station Code) shall be considered valid (i.e., acceptable for aircraft radio timing updates) if it is received within the validity window with respect to the previous beacon's timing reference. The validity window shall be defined to extend from –K(n+1)+1 to +1 symbol periods, where K = 4 for 4-slot configurations and K = 8 for 3-slot configurations and n is the squelch window parameter. To allow an aircraft radio to adapt in a timely manner to an abrupt change in the location of a beacon transmitter, an aircraft radio shall extend its validity window to include all relative times whenever its CTC1 counter exceeds 24.

Note: This definition takes into account the 1 symbol period accuracy assumed for the aircraft radio timing. It is also designed to support site diversity and selective keying operation, where it is desirable that the aircraft radio should base its timing on the signal from the closest ground site.

~~Due to the 1 symbol period accuracy assumed for the aircraft radio timing, the aircraft radio shall establish a validity window also equal to ±1 symbol period. A timing beacon shall be considered valid, i.e., acceptable for timing, if it is received within the validity window with respect to the previous beacon's timing reference.~~

3.3.2.1.3.1.2 Receipt of Beacon Information~~**Alternative Validity Window**~~

Aircraft radios shall decode and process information contained in any ground beacon signal with a Slot ID and Ground Station Code appropriate for the aircraft radio's current net.

Note: Although an aircraft radio must use the validity window to restrict which ground beacons it should use to update its timing, it should accept and react to any ground beacon associated with its net. This allows an aircraft radio to have its timing based on the closest ground site, while getting system information in the most timely manner.

~~To support selective keying operation, the alternative validity window is defined where the validity window is expanded so that any beacon within -K(n+1)+1 to +1 symbol periods is valid, where K = 4 for 4-slot configurations and K = 8 for 3-slot configurations and n is the squelch window parameter. (Note that the normal squelch window for voice reception is unchanged). To allow an aircraft to adapt in a timely manner to an abrupt change in location of a beacon transmitter, the aircraft radios shall extend its validity window to include all relative times whenever its counter CTC1 exceeds 24. The requirement to use the alternate validity window shall be indicated by transmitting an Aircraft ID = 62 in the polling field (see~~ Table G-~~4).~~

~~*Note: VDL Mode 3 Timing States are specified in Section 3.3.2.1.4.1.4.*~~

3.3.2.1.3.2 Parameter f (Free Running)

This parameter shall represent the maximum Coast Timing Counter 3 (CTC3) (Section 3.3.2.1.4.1.3) value beyond which the free running timing state 3 (TS3) is entered. This parameter shall represent the maximum number of MAC cycles of "coasting" which must elapse without receipt of a primary timing or Alternate Timing Signal (ATS) before transitioning to TS3. ATS is defined in Section 3.3.2.1.4.1.2.

> Note: *This parameter represents at least two whole polling cycles.*

3.3.2.1.3.3 Parameter NM1 (Maximum Retry)

The parameter NM1 shall represent the maximum number of retransmissions of a random access Reservation Request message.

3.3.2.1.3.4 Parameter RR (Reservation Request Randomizer)

The parameter RR shall specify the number of available time slots over which to select a time slot at random to transmit the Reservation Request message.

3.3.2.1.3.5 Parameter RE (Net Entry Request Randomizer)

The parameter RE shall specify the number of available time slots over which to select a time slot at random to transmit the Net Entry Request message.

3.3.2.1.3.6 Parameter RL (Leaving Net Randomizer)

The parameter RL shall specify the number of available time slots over which to select a time slot at random to transmit the Leaving Net message.

3.3.2.1.3.7 Parameter WR (Reservation Request Retransmission Delay)

The parameter WR shall specify the number of MAC cycles that an aircraft radio shall wait before attempting a Reservation Request message retransmission.

3.3.2.1.4 Description of Procedures

Media access shall observe the procedures described in this section in addition to observing the timing structure limitations of Section 3.3.2.1.2.1.

3.3.2.1.4.1 Timing Acquisition and Maintenance

3.3.2.1.4.1.1 Primary Timing Reference

~~The aircraft VDL shall derive its *primary timing* from the received M uplink burst (LBAC 11 for 3T configuration, either LBAC 5, 7, or 9 for 3S configuration, either LBAC 4 or 6 for 2S1X, and LBAC 5 for other configurations) associated with its assigned user group and Ground Station Code (GSC). The *timing reference point* shall be established based on the center of the first received symbol of the synchronization sequence at the antenna port of the M uplink burst associated with the user group assigned. VDL media access opportunities for transmitted bursts shall be set relative to this reference in terms of transmitted symbol periods as shown in Table 3-54, Table 3-55, and Table 3-56a.~~

~~*Notes:*~~

1. ~~*To remain in the normal timing state (TS1), an aircraft VDL should maintain its primary timing to within ± 1 symbol period of the correct time based on the position of the aircraft relative to the ground station. This timing tolerance is the basis for developing the timing state transition rules of Sections 3.3.2.1.4.1.4 and 3.3.2.1.4.1.5. Refer to Section 3.3.2.1.3.1 for this timing accuracy requirement.*~~

2. ~~*The relative timings among the TRPs of the different user groups are as shown in Table 3-56c.*~~

The aircraft station shall derive *its primary timing* from the received M uplink burst (LBAC 11 for 3T configuration, either LBAC 5, 7, or 9 for 3S configuration, either LBAC 4 or 6 for 2S1X, LBAC 9 for 1V3D, LBAC 7 for 1V2D, and LBAC 5 for other configurations) associated with its assigned user group and Ground Station Code. The *timing reference point* shall be established based on the center of the first received symbol of the synchronization sequence at the antenna port of the M uplink burst associated with the user group assigned. VDL Mode 3 media access opportunities for transmitted bursts shall be set relative to this reference in terms of transmitted symbol periods as shown in Table 3-54, Table 3-55, and Table 3-56a.

Notes: 1. To remain in the normal timing state (TS1), an aircraft station should maintain its primary timing to within ± 1 symbol period of the correct time based on the position of the aircraft relative to the ground station. This timing tolerance is the basis for developing the timing state transition rules of Sections 3.3.2.1.4.1.4 and 3.3.2.1.4.1.5. Refer to Section 3.3.2.1.3.1 for this timing accuracy requirement.

2. The relative timings among the TRPs of the different user groups are as shown in Table 3-56c.

3.3.2.1.4.1.2 Alternate Timing Reference

~~When required by the procedures of Section 3.3.2.1.4.1.3 through Section 3.3.2.1.4.1.5, the aircraft VDL shall derive alternate timing in truncate timing state 2 (TS2) from alternate timing sources (ATSs). ATSs are poll responses (except in the 3T configuration) associated with the user group or another user group (if available) and M uplink bursts in slots other than the one controlling the aircraft radio's user group received during that MAC cycle. This alternate timing shall be derived based on the first received symbol of the synchronization sequence of the received poll responses or uplink M bursts. The aircraft VDL shall accept timing from ATSs if they obey the following rule:~~

~~$T_r < T_a + 0.04 * CTC2 * T_s$~~

~~where T_a is the expected time of an ATS as determined by the aircraft radio's clock, T_r is the actual time of arrival of the ATS with respect to the aircraft radio's clock, CTC2 is the current value of the Coast Time Counter 2 defined in Section 3.3.2.1.4.1.3, and T_s is the symbol period. If CTC2 is greater than 800, *all* ATS time updates shall be accepted. If the time is updated, CTC2 is reset to 0.~~

When required by the procedures of Section 3.3.2.1.4.1.3 through Section 3.3.2.1.4.1.5, the aircraft station shall derive alternate timing in truncate timing state 2 (TS2) from alternate timing sources (ALT). ALT are poll responses (except in the 3T configuration) associated with the user group or another user group (if available) and M uplink bursts in slots other than the one controlling the aircraft radio's user group received during that MAC cycle.

An aircraft radio in TS0 will accept ATS timing originating from a ground station, yet remain in TS0, if the ground station M uplink burst indicates the aircraft radio is tuned to a data slot of a voice and data system configuration.

An aircraft radio in TS0 shall accept ATS timing originating from a ground station.

This alternate timing shall be derived based on the first received symbol of the synchronization sequence of the received poll responses or uplink M bursts. The aircraft station shall accept timing from ALT if they obey the rule

$$T_r < T_a + 0.04 * CTC2 * T_s$$

where T_a is the expected time of an ATS as determined by the aircraft radio's clock, T_r is the actual time of arrival of the ATS with respect to the aircraft radio's clock, CTC2 is the current value of the Coast Time Counter 2 defined in Section 3.3.2.1.4.1.3, and T_s is the symbol period. If CTC2 is greater than 800, *all* ATS time updates shall be accepted. If the time is updated, CTC2 is reset to 0.

3.3.2.1.4.1.3 Coast Timing Counters

The aircraft VDL shall maintain Coast Timing Counter 1 (CTC1), Coast Timing Counter 2 (CTC2), and Coast Timing Counter 3 (CTC3) in order to determine the timing state for each MAC cycle. CTC1, CTC2, and CTC3 shall be maintained per Table 3-59. The maximum value that each of the three CTC counters is allowed to increment to shall be 1023. Once a CTC counter reaches 1023, that CTC counter shall be held at that value indefinitely until reset is required in accordance with the rules stated in Table 3-59.

Table 3-59: Rules for CTCs' Maintenance

Timing Received in MAC cycle n-1	Action to update CTC1 in MAC cycle n	Action to update CTC2 in MAC cycle n	Action to update CTC3 in MAC cycle n
Primary	Reset to 0	Reset to 0	Reset to 0
Alternate	Increment	Reset to 0 if time is accepted, else increment	Reset to 0
None	Increment	Increment	Increment

Note: The rule for accepting Alternate Timing is defined in Section 3.3.2.1.4.1.2.

3.3.2.1.4.1.4 Timing States

The aircraft VDL shall take on one of four possible timing states for non-3T configurations - as determined by the CTCs as shown in Table 3-60. The timing states for 3T configuration are defined in Table 3-60a.

The aircraft VDL shall support transmissions of downlink M bursts and V/D (data) bursts only in Normal TS1 timing state. The aircraft VDL shall receive uplink M bursts and downlink M bursts in all timing states in order to extract timing information from all possible PTSs and ATSs.

Except in 3T configuration, the aircraft VDL shall enter truncate timing state 2 (TS2) from TS1 when the number of MAC cycles, which has elapsed without receiving a primary timing reference, exceeds the value of parameter t. Voice operation support during the different timing states is specified in Section 3.3.2.1.4.2.

Table 3-60: Timing States for Non-3T Configurations

Timing state	**CTC1 Value**	**CTC3 value**
Initial TS0***	max(f** -50,t*)	max(f** -50,t*)
Normal TS1	0 ≤ CTC1 < t*	0 ≤ CTC3 < t*
Truncate TS2	CTC1 ≥ t*	CTC3 < f**
Free Running TS3	CTC1 ≥ t*	CTC3 ≥ f**

* Defined in Section 3.3.2.1.3.1
** Defined in Section 3.3.2.1.3.2
*** For Net Initialization state, special rules apply (See Section 3.3.2.3.2.1.1)

Table 3-60a: Timing States for 3T Configuration

Timing state	**CTC1 value**	**CTC3 value**
Initial TS0***	Max(f** -50, t*)	max(f** -50, t*)
Normal TS1	0 ≤ CTC1< t*	0 ≤ CTC3 < t*
Transition (Non-Transmit)	CTC1 ≥ t*	CTC3 < f**
Free Running TS3	CTC1 ≥ t*	CTC3 ≥ f**

* Defined in Section 3.3.2.1.3.1

** Defined in Section 3.3.2.1.3.2

*** Net Initialization state, special rules apply (see Section 3.3.2.3.2.1.1)

3.3.2.1.4.1.4.1 Recommendation

An indication of the Transceiver timing state should be provided to the VDL Mode 3 aircraft user.

> Note: *The timing state controls operation of the Voice Unit (Section 3.3.5).*

3.3.2.1.4.1.5 Timing State Transitions

When in TS1, an aircraft station in non-3T configurations shall transition through TS2 before entering TS3. An aircraft station in 3T configuration shall transition from TS1 through a non-transmit transition period before entering TS3. When in TS3, the aircraft station shall accept time from any ATS and enter TS2. Any aircraft station shall immediately revert to TS1 upon reception of a valid primary timing signal.

During a PTT event, no timing state transition (except for transition to TS0 in response to a new tuning command) shall occur until that PTT event is completed. For data transmissions, a timing state transition shall be delayed (except for transition to TS0 in response to a new tuning command) until the current message transmission is completed. In the event that an aircraft station is engaged in a PTT event and a data event (transmit or receive) simultaneously, the timing state transition shall be delayed until both events are completed.

~~When in TS1, an aircraft VDL in non-3T configurations shall transition through TS2 before entering TS3. An aircraft VDL in 3T configuration shall transition from TS1 through a non-transmit transition period before entering TS3. When in TS3, the aircraft VDL shall accept time from any ATS and enter TS2. Any aircraft VDL shall immediately revert to TS1 upon reception of a valid primary timing signal.~~

~~During a PTT event, no timing state transition shall occur until that PTT event is completed. For data transmissions, a timing state transition shall be delayed until the current message transmission is completed. In the event that an aircraft VDL is engaged in a PTT event and a data event (transmit or receive) simultaneously, the timing state transition shall be delayed until both events are completed.~~

3.3.2.1.4.1.6 Dummy Poll Responses

When an aircraft radio receives an uplink M channel message with value 61 (Section G.2.1.4) in the Aircraft ID (Poll) field, indicating that the ground station does not support discrete addressing, an aircraft radio shall transmit dummy Poll Responses in downlink M slots reserved for Poll Response. The format of dummy Poll Responses shall be identical to a regular Poll Response. Dummy Poll Responses shall not be processed by the controlling ground station. The MAC cycle in which to transmit the dummy Poll Responses shall be chosen by the following algorithm:

Immediately after net initialization, after determining that the uplink Beacon contains Aircraft ID=61, divide all further MAC cycles into groups of 25. Within each group, choose one MAC cycle at random from 1 to 25 in which to transmit a dummy Poll Response. Continue to transmit dummy Poll Responses for as long as the aircraft radio remains in timing state TS1.

~~When an aircraft radio receives an uplink M channel message with value 61 or 62 (Section G.2.1.4) in the Aircraft ID (Poll) field, indicating that the ground station does not support discrete addressing, an aircraft radio~~

~~shall transmit dummy Poll Responses in downlink M slots reserved for Poll Response. The format of dummy Poll Responses shall be identical to a regular Poll Response. Dummy Poll Responses shall not be processed by the controlling ground station. The MAC cycle in which to transmit the dummy Poll Responses shall be chosen by the following algorithm:~~

~~Immediately after net initialization, after determining that the uplink Beacon contains Aircraft ID=61 or 62, divide all further MAC cycles into groups of 25. Within each group, choose one MAC cycle at random from 1 to 25 in which to transmit a dummy Poll Response. Continue to transmit dummy Poll Responses for as long as the aircraft radio remains in timing state TS1.~~

Notes:

1. *For the voice-only configurations: 4V, 3V, 3S and 2S1X, polling may not be implemented and a ground radio in one of these configurations may not support polling. In order to support the transmission of an Alternate Timing Reference in these configurations (see Section 3.3.2.1.4.1.2), aircraft radios must transmit "Dummy Poll Response" messages since they are never actually polled.*

2. *Analysis and simulation have shown that, unless the number of aircraft radios is extremely large, the probability that at least one MAC cycle out of 25 contains one and only one dummy Poll Response is very close to 1.*

3. *The LBACs available for dummy Poll Responses include LBAC 1 for configurations 4V, 3V, 3S, and 2S1X, irrespective of whichever LBAC is associated with the time slot the aircraft radio is currently connected to.*

3.3.2.1.4.2 Voice Operation Support

The aircraft station shall grant media access on a MAC cycle-by-MAC cycle basis based on the timing state and the voice signaling information received in the M uplink burst of the previous MAC cycle. The rules for media access shall be as described in Table 3-61. Furthermore, if Table 3-61 indicates 'Access', the MAC sublayer shall determine if there was a V/D (voice) burst in the previous TDMA frame from another user. If so, access shall be granted if the V/D (voice) header indicated an EOM; otherwise, the access shall be denied.

The MAC sublayer shall set the CTS flag for the Voice Unit (Section 3.3.5.4.3) when access is allowed; otherwise, the CTS flag is cleared.

The setting of the CTS flag for each TDMA frame shall coincide with the MAC timing associated with when the V/D (voice) burst is to be transmitted per Tables 3-54, 3-55, and 3-56 as appropriate. The conditions of both the timing state and the signaling shall be met in order to be granted access in a given MAC cycle. The aircraft station shall process received V/D (voice) bursts with correct Group ID while in timing states TS1 and TS2.

Notes:

1. *Reception of voice in TS0 is not required. Transmission of voice in TS0 is not permitted.*
2. *Reception and transmission of voice in TS3 are specified separately in Section 3.3.2.1.4.2.2 TS3 Voice Operation.*

The Voice Unit (Section 3.3.5) shall be notified of the timing state during each MAC cycle.

The maximum duration of an aircraft PTT event shall be limited to no more than 35 seconds (approximately 145 MAC cycles). The aircraft station shall automatically terminate the PTT event upon reaching this limit.

Table 3-61: Conditions for Voice Media Access (Aircraft Station)

	Voice Signal Field* Encoding		
Timing State	**Ground Access**	**Occupied**	**Voice Channel Idle**
Initial TS0 **	No Access	No Access	No Access
Normal TS1	No Access	Access permitted if access granted in previous MAC cycle	Access
Truncate TS2 ** (non-3T)	Access	Access	Access
Transition ** (3T only)	No Access	No Access	No Access
Free Running TS3 **	Access	Access	Access

* Defined in Appendix G, Section G.2.1.3.
** The aircraft station does not receive Voice Signal Field Encoding information in these cases.

Any aircraft station transmitting a voice signal shall cease transmitting if it receives a valid uplink M burst signal with the Voice Signal code set to any value other than 01 (binary) (occupied). (See Appendix G Section G.2.1.3.) This rule shall apply for the duration of the PTT event, starting 2 cycles after the first voice burst transmission.

Notes:

1. *Currently, only 3T system configuration supports voice reservation signaling.*
2. *It is desirable for implementation simplicity to be able to remain in the same timing state for the duration of a PTT event. Putting an upper limit on the duration of an aircraft PTT event makes this practical. This limit does not apply to the ground station because of normal AT operating procedures.*
3. *The 35 seconds limit on an aircraft PTT event is based on Automatic Termination of Transmission Requirement in RTCA/DO-207, "Minimum Operational Performance Standards for Devices That Prevent Blocked Channels Used in Two-Way Radio Communication Due to Unintentional Transmissions," January 25, 1991.*

~~The aircraft stationVDL shall grant media access on a MAC cycle-by-MAC cycle basis based on the timing state and the voice signalling information received in the M uplink burst of the previous MAC cycle. The rules for media access shall be as described in Table 3-61. The conditions of both the timing state and the signalling shall be met in order to be granted access in a given MAC cycle.~~

~~The Voice Unit (Section 3.3.5) shall be notified of the timing state during each MAC cycle.~~

~~The maximum duration of an aircraft PTT event shall be limited to no more than 35 seconds (approximately 145 MAC cycles). Aircraft stationVDL shall automatically terminate the PTT event upon reaching this limit.~~

~~Table 3-61: Conditions for Voice Media Access (Aircraft StationVDL)~~

	~~Voice Signal Field* Encoding~~		
~~Timing State~~	**~~Ground Access~~**	**~~Occupied by Aircraft User~~**	**~~Voice Channel Idle~~**
~~Initial TS0 **~~	~~No Access~~	~~No Access~~	~~No Access~~
~~Normal TS1~~	~~No Access~~	~~Access permitted if access granted in previous MAC cycle~~	~~Access~~
~~Truncate TS2 ** (non-3T)~~	~~Access~~	~~Access~~	~~Access~~
~~Transition ** (3T only)~~	~~No Access~~	~~No Access~~	~~No Access~~
~~Free Running TS3 **~~	~~Access~~	~~Access~~	~~Access~~

~~* Defined in Appendix G, Section G.2.1.3.~~

~~** The aircraft stationVDL does not receive Voice Signal Field Encoding information in these cases.~~

~~Any aircraft stationVDL transmitting a voice signal shall cease transmitting if it receives a valid uplink M channel signal with the Voice Signal code set to any value other than 01 (binary) (occupied by aircraft user). (See Appendix G Section G.2.1.3.) This rule shall apply for the duration of the PTT event, starting 2 cycles after the first voice burst transmission.~~

~~Notes:~~

1. *~~Currently, only 3T system configuration supports voice reservation signalling.~~*

2. *~~It is desirable for implementation simplicity to be able to remain in the same timing state for the duration of a PTT event. Putting an upper limit on the duration of an aircraft PTT event makes this practical. This limit does not apply to the ground station because of normal AT operating procedures.~~*

3. *~~The 35 seconds limit on an aircraft PTT event is based on Automatic Termination of Transmission Requirement in RTCA/DO-207, "Minimum Operational Performance Standards for Devices~~*

~~That Prevent Blocked Channels Used in Two-Way Radio Communication Due to Unintentional Transmissions," January 25, 1991.~~

3.3.2.1.4.2.1 User Notification

The aircraft station shall notify the users if any of the following events occurs:

a) Voice transmission (including unintentional transmission) is stopped when received uplink M burst voice signal code is other than 01_b,
b) PTT event exceeds the 35-second limit,
c) PTT is asserted while access is not allowed (see Table 3-61).

Note: The methods used for user notification are beyond the scope of this document. Notification to the user could, as an example, be implemented as signalling to the transceiver external interface or implemented as a short duration audible signal that is mixed with the received audio.

3.3.2.1.4.2.2 Free Running Voice Operation

While in TS3, the aircraft station shall process all V/D (voice) bursts without regard to Group ID. Multiple V/D (voice) bursts with different Group ID shall be processed on a first-come-first-serve basis, regardless of Group ID. Once a particular V/D (voice) burst is processed, the aircraft station shall continue to process only V/D (voice) bursts from the same user until EOM is indicated.

The aircraft station in TS3 timing state shall maintain system timing autonomously. While in TS3, the aircraft station shall transmit V/D (voice) bursts in the assigned time slot based on the system timing maintained by the aircraft.

Note: Without beacons and ALT available to correct its time, an aircraft station in TS3 is expected to drift relative to UTC at a rate determined by the stability of its reference oscillator

3.3.2.1.4.3 Link Management Support

3.3.2.1.4.3.1 Polling

When directed by the ground LME, the ground MAC sublayer shall transmit a Poll Request message. The aircraft MAC sublayer shall deliver a received Poll Request message to the aircraft LME. Upon receiving a Poll Response from the aircraft LME, the aircraft MAC sublayer shall stop the Reservation Request retransmission using the random access M-channel until a new request is generated. The aircraft

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station shall respond to a poll by the ground station by transmitting a Reservation Request message in LBAC 2, 3, or 4 for 3T configuration, and LBAC 1 for other configurations in the MAC cycle immediately following the poll. This opportunity to request a reservation shall be consistent with the procedures of Section 3.3.2.1.4.4.3.3.3. If no reservation is needed by the aircraft ~~VDL~~station, the Number of Slots Requested field and the Voice Request field shall be set to zero.

The ground MAC sublayer shall deliver a received Poll Response message to the ground LME. The ground station shall respond to a Reservation Request message contained in a Poll Response using the procedures identified in Sections 3.3.2.1.4.4.3.3.1 and 3.3.2.1.4.4.3.3.3. No response shall be sent by the ground station if the number of slots in the reservation field is zero.

3.3.2.1.4.3.2 Net Entry Request Message

When directed by the LME (Section 3.3.2.3), the aircraft MAC sublayer shall transmit a Net Entry Request message. The MAC sublayer shall attempt transmission in LBAC 1, 2, 3, 4, 5, 7, 9, 13, 15, or 17 for 3T configuration, LBAC 1, 3, or 7 for 2V2D, LBAC 3, 5, 7, 11, 13, or 15 for 1V3D configuration, LBAC 3, 5, 9, 11 for 1V2D configuration, and LBAC 1 for 4V, 3V, 3S, 2S1X, 3V1D, and 2V1D configurations, when these LBACs are available for random access (RA) on a slotted Aloha basis.
~~The MAC sublayer shall attempt transmission in LBAC 1, 2, 3, 4, 5, 7, 9, 13, 15, or 17 for 3T configuration, LBAC 1, 3, or 7 for 2V2D configuration, and LBAC 1 for 4V, 3V, 2S1X, 3V1D, and 2V1D configurations, when these LBAC channels are available for random access (RA) on a slotted Aloha basis.~~

Transmission attempts for the Net Entry Request message shall be based on the algorithm of Appendix I for selecting an appropriate downlink M-burst LBAC to transmit the Net Entry Request message. The parameter RE (defined in Section 3.3.2.1.3.5) is a MAC Service System Parameter. The value of RE is given in Table 3-58b. This procedure shall be terminated when a valid Net Entry Response message is received or the number of retransmissions exceeds NL1 (see Table 3-66a).

3.3.2.1.4.3.3 Next Net Message

When directed by the ground LME, the ground MAC sublayer shall transmit a Next Net message. Transmission of the Next Net message shall occur in two consecutive cycles.

Upon receipt of two consecutive Next Net messages containing the same information, the aircraft MAC sublayer shall provide the received Next Net information to the aircraft LME.

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When directed by the aircraft LME the aircraft MAC sublayer shall transmit a Next Net ACK message to the ground station in response to the next Poll Request. Upon receipt of the Next Net ACK message, the ground MAC sublayer shall deliver the acknowledgement to the ground LME.

If the ground LME fails to receive a Next Net ACK in response to the next Poll Request, the ground LME shall retransmit the Next Net message to the aircraft LME through the MAC sublayer in the next available uplink M ~~channel~~burst. Next Net retransmission shall also be transmitted in two consecutive cycles. The Next Net retransmission shall stop when the value of the polling reply counter NL2 is exceeded. Additionally, Next Net transmission is also terminated upon receipt of the Leaving Net Message.

> *Note: See Sections 3.3.2.3.2.6.1 and 3.3.2.3.2.6.2 for additional details regarding the receipt of the Leaving Net message and the Polling Reply Counter.*

In the case that the aircraft station has both a Reservation Request message and a Next Net ACK message to transmit when polled, the Next Net ACK message shall be transmitted.

The Next Net ACK message format is as defined in Appendix G, Section G.2.13.

3.3.2.1.4.3.4 Leaving Net Message

When directed by the LME (Section 3.3.2.3), the aircraft MAC sublayer shall select an appropriate downlink M burst LBAC to transmit a Leaving Net Message based on the algorithm of Appendix I. There shall be no retransmission of a Leaving Net message.

The aircraft station shall stop all transmitting and receiving activities on that net after the aircraft MAC sublayer sends the Leaving Net message.

~~When directed by the LME (Section 3.3.2.3), the aircraft MAC sublayer shall select an appropriate downlink M-burst LBAC to transmit a Leaving Net Message based on the algorithm of Appendix I. There shall be no retransmission of a Leaving Net message.~~

3.3.2.1.4.3.4.1 Tuning to Next Net

Upon completion of the Leaving Net message transmission, the aircraft LME shall automatically tune to the next net, provided that the aircraft LME has received the Next Net information.

Notes:

1. It is not necessary for the aircraft to acknowledge the Next Net message to initiate Leaving Net message transmission.
2. See Section 3.7.2 for tuning performance requirements.

3.3.2.1.4.3.5 Terminate Net Message

Upon reception of the Terminate Net message, the aircraft MAC shall clear the Local ID association and revert to an aircraft ID of 61, and notify the LME of the loss of discrete-addressed services. The Terminate Net message format shall be as defined in Section G.2.14. After the receipt of the Terminate Net message, the aircraft station shall begin the delayed net entry procedures described in Section 3.3.2.3.2.1.2.

3.3.2.1.4.3.6 Supported Options Message

The ground LME shall transmit the Supported Options message in response to the initial Poll Response of an aircraft entering the net. The aircraft MAC sublayer shall provide the supported options information to the aircraft LME.

Note: See Section 3.3.2.3.2.1.2.1 for LME actions and Table G-9 for options supported.

3.3.2.1.4.3.7 Multiple Radio Installations

If multiple radios are installed on an aircraft station and are operating on the same channel, the radio systems shall coordinate their MAC sublayers, as necessary, so that only one radio acknowledges to polls and next net messages, and that one radio acknowledges uplink V/D (data) uplink bursts.

Note: This requirement is to resolve issues with multiple radios tuned to the same net, or for system configurations 3V1D/2V1D with multiple radios sharing the same data slot regardless of different local identifiers. Arbitration of downlink messaging in these cases is already handled by the router.

3.3.2.1.4.4 Data Operation Support

3.3.2.1.4.4.1 Segmentation Function

The MAC sublayer shall perform segmentation of the user message longer than one data burst, as received from the upper layer, to support data burst transmission. The segmentation function shall observe the following procedures:

- Each segment shall occupy an entire data burst and shall set the EOM field of the Header segment to 0. Each segment of the user message shall include the Segment Number in the Segment Number field of the Header segment of each V/D (data) burst. The Segment Number shall begin with 1 for the first segment and shall be incremented by 1 for subsequent segments. The final segment of the user message shall set the EOM field to 1 to indicate to the peer MAC entity that the user message is completed. A Segment Number of 0 is reserved.

- All downlink segments of the user message shall occupy only the time slots indicated in the Reservation Response field of the M uplink (Normal Message) burst (Section G.2.2.1~~ of Appendix G~~) and shall be transmitted in consecutive burst opportunities.

- Any missing or corrupted segments shall result in discarding of the entire user message.

> *Note:* *The Maximum user message size is established by the maximum DLS frame group size assuring containment within a maximum of 15 V/D (data) bursts (Section 3.3.2.2.3.2).*

3.3.2.1.4.4.2 Uplink Data Transfer

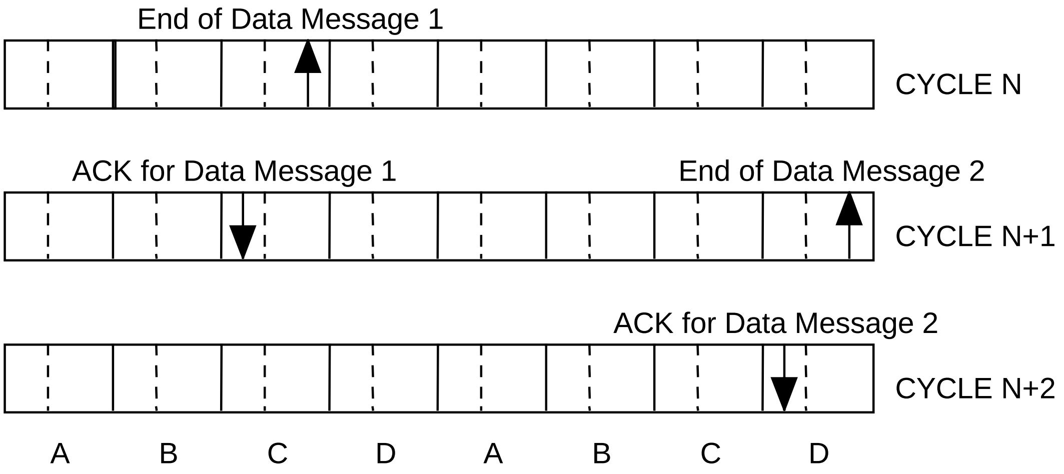
The VDL ground station shall determine burst scheduling for uplink user message transmission.

> *Note:* *The ground station is limited to transmission of DLS Information (I) frames to a single aircraft in any given V/D (data) burst in order for the acknowledgment process to work properly.*

3.3.2.1.4.4.2.1 Acknowledgement Protocol

Upon receipt of an ACK frame from the local DLS sublayer, an Acknowledgment message shall be transmitted in the M burst downlink subchannel associated with the same slot one MAC cycle after the receipt of the last burst of the message being acknowledged, as illustrated in Figure 3-7. The downlink ACK frame shall not be transmitted in a V/D (data) burst. The peer MAC sublayer shall restore the ACK frame and forward it to the local DLS sublayer.

Figure 3-7: M- Burst ACK Timing



Note: *The protocol used by the DLS must ensure an explicit ACK frame is issued in time to be transmitted in the proper M burst in the following MAC cycle. Transmitting an explicit acknowledgment in the designated M downlink burst improves channel efficiency and response time relative to transmission of the ACK frame via a V/D (data) burst and requiring the reservation request procedure.*

3.3.2.1.4.4.3 Downlink Data Transfer

3.3.2.1.4.4.3.1 Data Transfer

The MAC sublayer shall transmit downlink data in Normal timing state only.

Note: *The aircraft MAC can not transmit downlink M bursts when it is not in Normal timing state.*

3.3.2.1.4.4.3.2 Assemble Message for MAC Data Transfer

Every MAC cycle, the MAC sublayer shall determine if the transmit queue manager has traffic to be transmitted. The existence of traffic in the transmit queue manager shall cause the MAC sublayer to initiate the data transfer procedure described in Sections 3.3.2.1.4.4.3.3 through 3.3.2.1.4.4.3.6 below.

3.3.2.1.4.4.3.3 Request a Reservation

3.3.2.1.4.4.3.3.1 Reservation via Slotted Aloha Random Access

When downlink data traffic is offered by the transmit queue manager, or an access signal is received from the Voice Unit, the MAC sublayer shall select a downlink M-burst LBAC from the available RA LBACs to transmit the Reservation Request message based on the process of Appendix I and the random number generation algorithm of Appendix H. The parameters RR and WR (defined in Sections 3.3.2.1.3.4 and 3.3.2.1.3.7) are MAC Service System Parameters. The values for these parameters are given in Table 3-58b.

Before a Reservation Response message is received with slot assignment, the aircraft shall be allowed to modify, cancel, or replace the outstanding request with a new request, provided that the number of slots for the new request is less than or equal to that of the original request. If a Reservation Request is received with no slots requested, the ground station shall automatically cancel the outstanding request.

After a Reservation Response message is received with slot assignment for a frame group, which contains acknowledged frames, the aircraft radio shall stop retransmitting the outstanding request. The aircraft radio shall not attempt to send any Reservation Request messages until 1) after receiving an acknowledgement of correct reception of the current V/D (data) transmission or 2) upon T1 timer expiration.

After a Reservation Response message is received with slot assignment for a frame group, which contains no acknowledged frames, the aircraft radio shall stop retransmitting the outstanding request. The aircraft radio shall be allowed to send a new Reservation Request message, regardless of whether or not the associated new frame group contains acknowledged frames.

Notes:

1. *3T system configuration is currently the only configuration where an access signal is issued by the Voice Unit.*
2. *The available random access LBACs depend on process type and configuration. LBACs scheduled for Poll Responses and downlink ACKs are removed from the lists.*

3.3.2.1.4.4.3.3.2 Reservation Request Acknowledgement

Upon receipt of a valid Reservation Request, the ground station shall respond with a Reservation Response message. This message shall be either a reservation or a Reservation Request Acknowledgement (RACK).

A Reservation Response message with slot assignment shall be sent to convey the actual slot assignment to the requester. A Reservation Response message with RACK shall be sent to the requester if the ground station is unable to honor the request due to unavailability of the time slots. The Reservation Response message with RACK shall not be sent in response to a Poll Response that cannot be immediately granted.

If the aircraft is scheduled to be polled before a Reservation Response message (with either slot assignment or RACK) can be generated, the ground station shall send the Poll Request to the aircraft as scheduled, wait for the Poll Response, and send a Reservation Response or no response, as required.

Upon receiving a Reservation Response message with RACK, the aircraft radio shall stop retransmitting the pending request, but shall continue to respond to Poll Request with a Poll Response (see Section 3.3.2.1.4.4.3.3.3).

Notes:

1. *The Reservation Request Acknowledgement message is a special Reservation Response message (described in Appendix G Section G.2.2.1) with value 0001 (binary) in the Reserved Slot.*

2. *RACK is not a proper ground station response to a Poll Response message except to the first Poll Response during net entry.*

3.3.2.1.4.4.3.3.3 Reservation via Poll Response

Aircraft shall be allowed to use the Poll Response to reaffirm, to modify, or to cancel the outstanding request, or to replace the outstanding request with a new request. The new Reservation Request shall have no limitation on the number of time slots requested, other than that the maximum number of V/D (data) bursts requested is consistent with the value of parameter N1 (as defined in Section 3.3.2.2.3.2). Upon receiving a Poll Response, the ground station shall automatically replace the outstanding request with the new request. If a Poll Response for the new request is received with no slots requested, the ground station shall automatically cancel the outstanding request. If the Poll Response is not received, the ground station shall cancel the outstanding request. The aircraft shall wait for the next poll opportunity to retransmit the request or transmit a new request.

The rules described in Section 3.3.2.1.4.4.3.3.1 on sending a new reservation request after the aircraft has received a Reservation Response message with slot assignment for the outstanding request shall apply when the outstanding request is via Poll Response.

Note: The difference between replacing an outstanding Reservation Request through Poll Response and Slotted Aloha Random Access is that more time slots can be requested in Poll Response, while the number of time *slots of the new request has to be equal to or less than the outstanding request in the case of random access.*

3.3.2.1.4.4.3.4 Reservation Request Retransmission

The aircraft station shall select a downlink M burst LBAC for random access Reservation Request Retransmission based on the process of Appendix I and the random number generation algorithm of Appendix H. The Reservation Request Retransmission shall be repeated until one of the following occurs: (1) a valid response is received, (2) a poll is received, or (3) the number of retransmissions exceeds NM1 (defined in Section 3.3.2.1.3.3). The value for NM1 is given in Table 3-58a. When the number of reservation request retransmissions exceeds NM1, random access reservation request retransmission shall be terminated. After the random access reservation request retransmissions have been terminated, the aircraft station shall continue to provide the data reservation in poll responses.

~~The aircraft radio shall select a downlink M-burst LBAC for random access Reservation Request Retransmission based on the process of Appendix I and the random number generation algorithm of Appendix H. The Reservation Request Retransmission shall be repeated until one of the following occurs: (1) a valid response is received, (2) a poll is received, or (3) the number of retransmissions exceeds NM1 (defined in Section 3.3.2.1.3.3). The value for NM1 is given in Table 3-58a. When the number of reservation request retransmissions exceeds NM1, the reservation request retransmission shall be terminated and the LME (Section 3.3.2.3) shall be notified.~~

3.3.2.1.4.4.3.5 Reservation Confirmation Indication

Upon receipt of a Reservation Response (Appendix G, Section G.2.2) signaling an "access scheduled," the MAC sublayer shall authorize transmission of all segments of the user message starting in the slot indicated.

3.3.2.1.4.4.3.6 Acknowledgment Protocol

Acknowledgments of downlink transmissions transmitted by the ground station shall be processed by the aircraft DLS to indicate completion of downlink data transfer.

3.3.2.1.4.5 MAC Data Frame Transmission

After each transmission that requires acknowledgement, the MAC sublayer shall maintain a retransmission timer T1 for destination. This timer is the time that the MAC sublayer shall wait for an acknowledgement prior to a new transmission. Timeout of the T1 timer shall result in a request to the DLS for a new frame group. This implies that the VDL shall replace the retransmission of the outstanding frame group with the transmission of a new frame group, if the new frame group has higher priority frames. The number of successive T1 timer expirations to a specific destination shall not exceed N2 times. The LME shall be informed when the successive T1 timer expirations exceeds N2 times, signaling it to terminate the link to that destination. The N2 counter shall be reset upon the successful acknowledgement of the message.

The maximum transmission delay for an uplink ACK for a VDL Mode 3 ground station shall not exceed T_ack, where T_ack is in MAC cycles. The delay associated with transmitting an uplink ACK is defined from the time the last V/D (data) burst is received to the time that the ACK transmission begins. If the ground station is unable to transmit the ACK within T_ack after the receipt of the last downlink V/D (data) burst, it shall not transmit the ACK. For aircraft stations, the specific downlink M channel for ACK transmission is defined in Section 3.3.2.2.5.2.

The MAC data frame transmission system parameters T1, T_ack, and N2 shall be as defined in Table 3-62.

> Note: *Upon T1 timer expiration and depending upon the message priorities of the current message queues, the new frame group generated by the DLS sublayer to be sent to the MAC sublayer for transmission may not include the previously transmitted acknowledged frames, which are associated with event of the T1 timer expiration.*

Table 3-62: MAC Data Frame Transmission System Parameters

Symbol	Parameter Name	Minimum	Maximum	VDL Mode 3 Default	Increment
T1 (MAC cycles)	Delay before retransmission (ground)	1	40	2	1
	Delay before retransmission (aircraft)	2	40	10	1
T_ack (MAC cycles)	Maximum delay allowable for ACK (ground only)	1	40	9	1
N2	Maximum number of successive T1 timer expirations	1	20	3*	1

** For T1 (ground) = 2 and T1 (aircraft) = 10.*

3.3.2.1.4.6 Automated Handoff for 3T Configuration

System configuration 3T shall support automated handoff of ground stations for aircraft stations, which are capable of re-tuning frequencies within 2 ms. LBAC 12 shall be broadcast by all participating ground stations permitting an aircraft station to listen to all nearby ground stations (one station per MAC cycle) and determine which ground station provides the strongest signal. In the LBAC 12 burst, the current ground station shall broadcast its Ground Station Code, the Ground Subnetwork Address of the GNI attached to the router and the frequencies of the next four proximate nets to be monitored. The aircraft station shall scan through these Adjacent Frequencies in LBAC 12 and compare signal quality from the ground stations.

After scanning the last Adjacent Frequency, the aircraft station shall scan the current ground station frequency again, which may contain different Adjacent Frequency information if there are more than four nets to be monitored. The aircraft station shall accumulate and maintain a database of all nearby nets to be scanned, including frequency, Ground Station Code, and their latest signal quality measurement.

When the signal quality from a proximate ground station is determined to provide a better link than the one provided by the current ground station in accordance with an algorithm selected by the equipment manufacturer, the aircraft station shall initiate an automatic handoff to the new ground station. If the aircraft station cannot acquire the new net, it shall attempt to acquire other nets and the previous net, in descending order of quality. If the aircraft station cannot locate a new ground station, the LME shall be notified. If at any time no LBAC 12 signals are received, the LME shall be notified.

Notes:

1. *The signal quality comparison should be such that the handoff decision is relatively resilient to short term signal fading.*

2. *It is recommended that the algorithm include a signal quality threshold such that handoff can only take place when the signal quality is below the threshold. This recommendation is provided so handoff will not take place if the existing link is healthy and is with ample margin.*

3. *It is also recommended that the handoff algorithm consider the Ground Subnetwork Address of the new ground station in an attempt to minimize changes in the IDRP connection where possible by providing some preference to ground stations connected to the same router as the current connection.*

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3.3.2.2 Data Link Services (DLS) (VDL Mode 3)

3.3.2.2.1 Services

The DLS sublayer services shall be carried over the TDMA V/D (data) slot. These services shall include error detection and recovery, and address identification.

> Note: *Frame sequencing is assumed to be provided by the Media Access Control protocol.*

3.3.2.2.1.1 Error Detection

Error detection shall be provided by a 24-bit Frame Check Sequence (FCS) generated by the 24-bit CRC-24Q polynomial computed over the entire frame. This FCS shall be overlaid on the 24-bit aircraft station address with an exclusive-OR operation. The polynomial used for the FCS shall be as follows:

$$x^{24}+ x^{23}+ x^{18}+ x^{17}+ x^{14}+ x^{11}+ x^{10}+ x^{7}+ x^{6}+ x^{5}+ x^{4}+ x^{3}+ x+ 1$$

3.3.2.2.1.2 Address Identification

The link layer header shall contain the aircraft station address.

> Note: *The ground station address is implied by the frequency and slot assignment.*

3.3.2.2.1.2.1 Address Uniqueness

All aircraft stations shall be uniquely addressed by the 24-bit ICAO address.

3.3.2.2.1.2.2 Broadcast Addressing

~~The~~ VDL Mode 3 shall support broadcast addresses that are recognized and acted upon by all appropriate receivers. Broadcast addressing service shall be as defined in Section 3.3.2.2.4.2.

3.3.2.2.1.3 Data Transfer

Data shall be transferred in the information fields of VDL INFO and CTRL frames. One and only one subnetwork packet shall be contained in an INFO frame.

3.3.2.2.2 VDL Mode 3 Data Link Service Protocol Specification

3.3.2.2.2.1 Frame Format

The data link protocol data units (DLPDUs) shall be formatted as specified in Figure 3-8. Unless indicated otherwise, the first bit transmitted and received shall represent the least significant bit (LSB) in each field and subfield.

Note: A transmitter may include more than one frame in a single MAC sublayer access event so long as only one destination is required to acknowledge.

Description	**Octet**	First bit trans-mitted ↓	**Bit Number**						
		1	2	3	4	5	6	7	8
FCS/Aircraft Address Field	1	Aircraft Station Address							
	2	XOR							
	3	24-bit FCS							
Link Control	4	Address Type			T	MF	Frame Type/Priority		
Data Control 1	5	Ground Subnetwork Address						DL [MSB]	
Data Control 2	6	Data Length (DL) [LSB], N							
Information	7..N+6	User Data							

Figure 3-8: DLS Sublayer Frame Format

3.3.2.2.2.2 FCS/Aircraft Address Field

The FCS/Aircraft address field shall consist of three octets for the FCS/aircraft station address subfield and 3 bits for the address type subfield.

3.3.2.2.2.2.1 FCS/Aircraft Station Address

The FCS/aircraft station address subfield shall be the 24-bit ICAO aircraft address combined with the 24-bit FCS described in Section 3.3.2.2.1.1 via an exclusive-OR operation. The most significant byte shall be encoded in Octet 1 of the frame and the least significant byte shall be encoded in Octet 3.

Note: In sections referring to VDL Mode 2, this 24-bit ICAO aircraft address is referred to as the Aircraft Specific Address.

3.3.2.2.2.2.2 Address Type

The address type subfield shall consist of three bits which indicate the usage of the remaining 24 bit aircraft address. The most significant bit is bit 3 in Figure 3-8. The following table lists the address type options.

Code	Description
000	Frame transmitted by the ground station to the specified aircraft (discretely addressed)
001	Frame transmitted by the specified aircraft to the ground station (discretely addressed)
010-110	Spare
111	Frame transmitted by the ground station to all aircraft, the 24-bit aircraft station address shall be set to all binary 1's (broadcast).

Notes:

1. *This field will indicate to the receiver whether the aircraft station address or broadcast address should be used to decode the FCS.*

2. *For the ground station, the MAC sublayer can provide the 6-bit Aircraft Identifier via primitives to the DLS to determine which aircraft station address to use to extract the FCS.*

3.3.2.2.2.3 Link Control Field

The Link Control Field consists of the 3-bit Frame Type/Priority subfield, the More Frame (MF) bit, and the Toggle (T) bit, as shown in Figure 3-9.

		Link Control Field Bit Encoding				
	Frame Type	**4**	**5**	**6**	**7**	**8**
Management Frames	CTRL_CMD (Control Command)	T	MF	0	0	1
	CTRL_RSP (Control Response)	T	MF	1	0	1
	reserved	T	MF	0	1	1
	ACK (Acknowledge)	T	MF	1	1	1
Data Frame	INFO (Information)	T	MF	Priority		0

Figure 3-9: VDL Mode 3 Link Control Field

3.3.2.2.2.3.1 Frame Type

The variable length subfield for frame type identifies the purpose of the information contained within the frame. INFO frames shall carry user data, ACK frames shall be used to indicate correct transmission of frames, and CTRL frames shall be used to communicate link control information. This field shall consist of one bit for Data frames or three bits for Management frames.

3.3.2.2.2.3.2 Priority

The priority subfield supplies the priority of the frame for processing. This subfield shall be only included for Data frames. The 16 levels of priority supported by the ATN for the CLNP subnetwork interface are grouped into four VDL Mode 3 frame priority categories which shall be encoded in the 2-bit priority field per Table 3-63. The VDL PLP subnetwork interface groups the 16 ATN priority levels down to only two priority levels, high or low, which are mapped into the same 2-bit priority field also designated in Table 3-63. CTRL_CMD, CTRL_RSP, and ACK frames are always management priority and shall assume a priority of 3, hence they do not need this information encoded in the frame header. The priority field shall be encoded such that bit 7 of Figure 3-9 is the most significant bit.

> Note: *It should be recognized that for the VDL PLP interface, Network Management traffic will be grouped with the other high priority application traffic using priority 2, rather than the CLNP interface which maps it to priority 3. This is to prevent the link layer management traffic from being blocked by application level traffic. The DLS supporting the VDL PLP interface will not use priority 1.*

Table 3-63: VDL Mode 3/ATN Priority Mapping

Priority Bit Field	ATN Priority	VDL PLP Priority	VDL Mode 3 Priority
11	14. Network/Systems Management		Management
10	13. Distress Communications 12. Urgent Communications 11. High Priority Flight Safety Messages 10. Normal Priority Flight Safety Messages	HIGH	Urgent/Flight Safety
01	9. Meteorological Communications 8. Flight Regularity Communications		Meteorological and Flight Regularity
00	7. Aeronautical Information Service Messages 6. Network/Systems Administration* 5. Aeronautical Administration Messages* 4. <unassigned> 3. Urgent Priority Administrative and UN Charter Communications* 2. High Priority Administrative and State/Government Communications* 1. Normal Priority Administrative* 0. Low Priority Administrative*	LOW	Aeronautical Information

* AM(R)S frequencies are restricted to safety of flight messaging, hence regulations currently prohibit the use of priorities 0-6 over the VHF aeronautical band.

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3.3.2.2.2.3.3 More Frame

The MF subfield shall be encoded as "1" during the frame grouping process to indicate that more frame(s) are to follow and shall be encoded as a "0" if the current frame is the last frame of a grouped frame.

3.3.2.2.2.3.4 Toggle

The Toggle (T) subfield shall alternate between "0" and "1" for each unique acknowledged frame group (see Section 3.3.2.2.4.3.1.3) being sent. Reception of an ACK frame shall trigger the toggling of the bit. The receiver shall consider successive acknowledged frame groups with the same setting ~~to~~of the T bit as duplicates and shall discard acknowledged frames whose T bit does not change value from the previously received frame group containing acknowledged frames. The receiver shall still send an ACK frame for each group correctly received. The DLS shall ignore this bit for unacknowledged frames.

Note: The ground station needs to maintain separate T bit states for each aircraft connected.

~~3.3.2.2.2.3.4 Toggle~~

~~The Toggle (T) subfield shall alternate between "0" and "1" for each unique acknowledged frame group (see Section 3.3.2.2.4.3.1.3) being sent. Reception of an ACK frame shall trigger the toggling of the bit. The receiver shall consider successive acknowledged frame groups with the same setting to the T bit as duplicates and shall keep only the last correctly received group. The receiver shall still send an ACK frame for each group correctly received. The DLS shall ignore this bit for unacknowledged frames.~~

Note: ~~*The ground station needs to maintain separate T bit states for each aircraft connected.*~~

3.3.2.2.2.4 Data Control Field

The data control field shall consist of a 6-bit Ground Subnetwork Address subfield followed by a 10-bit Data Length subfield. ACK frames do not contain the Data Control field.

3.3.2.2.2.4.1 Ground Subnetwork Address Subfield

The ground subnetwork address subfield shall contain a 6-bit number, unique with respect to adjacent facilities, used to identify the ground subnetwork entity used to communicate with the aircraft user. The binary value of 000000 shall be reserved to indicate Unknown Subnetwork Address. This is used during the connection establishment phase when an aircraft DLS may not yet know the appropriate subnetwork address to use.

Note: The Ground Subnetwork Address must be unique with respect to the adjacent facilities, so that during handoffs between routing domains, the link layer can uniquely identify the subnetwork entity to process the packet with respect to current or next facility.

3.3.2.2.2.4.2 Data Length Subfield

The data length subfield shall contain a 10-bit number representing the number of octets contained within the Information Field.

3.3.2.2.2.5 Information Field

The information field shall contain user data. This field shall not be present for ACK frames.

3.3.2.2.3 Data Link Service System Parameters

The parameters needed by the DLS sublayer shall be as listed in Table 3-64 and detailed in Sections 3.3.2.2.3.1 through 3.3.2.2.3.2.

Table 3-64: DLS System Parameters

Symbol	Parameter Name	Minimum	Maximum	VDL Mode 3 Default	Increment
T3	Link initialization time (MAC cycle)	1	30	25	1
N1*	Maximum from-aircraft and to-aircraft frame group size	16 octets	930 octets	930 octets	1 octet

* N1 is defined to be the maximum size of a frame group including frame headers of the individual component frames. In the case of a single ungrouped frame the maximum frame size excluding its frame header is 924 octets.

3.3.2.2.3.1 Timer T3 (Link Initialization Time)

Timer T3 shall be the time that a data link entity waits for a CTRL_RSP frame before retransmitting a CTRL_CMD frame. Timer T3 shall be started upon transmission of a CTRL_CMD frame.

3.3.2.2.3.2 Parameter N1 (Maximum Frame Group Size)

The N1 parameter shall indicate the maximum frame group size in octets. The value of parameter N1 includes all DLS frame headers of its component frames.

~~The N1 parameter indicates the maximum frame group size in octets. The value of parameter N1 includes all DLS frame headers of its component frames. The maximum INFO frame that a station can accept shall be limited by the parameter N1 minus 6 octets for the DLS frame header.~~

3.3.2.2.4 Description of Procedures

The VDL data link operation procedure shall follow procedures described in the following subsections.

3.3.2.2.4.1 Modes of Operation

3.3.2.2.4.1.1 Operational Mode

The DLS shall operate in asynchronous balanced mode at all times.

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Note: Either station may send messages at any time and the stations are considered peers with respect to management of the data link.

3.3.2.2.4.2 Broadcast

Only INFO and CTRL_CMD frames shall be broadcast. For broadcast frames, the address and address type fields shall be set to all binary 1's.

3.3.2.2.4.3 Information Transfer

The information transfer procedure shall be as described in the following sections.

3.3.2.2.4.3.1 Transmission Queue Management

The management frames (ACK, CTRL_CMD, and CTRL_RSP) shall be classified as network management messages and prioritized accordingly.

3.3.2.2.4.3.1.1 Priority Processing

Each information frame shall be assigned a priority number by the link layer according to the priority parameter received from the subnetwork. The number of information frame priorities shall be as defined in Section G.2.10.2. Frames shall be forwarded to the MAC sublayer on a first-in/first-out manner within each priority level, with the exception that link layer management frames shall have precedence over other network management traffic.

3.3.2.2.4.3.1.2 Recommendation for Frame Grouping

To reduce the number of media accesses, as new information frames arrive at the transmission queue, they should be checked for priorities and grouped in their order of arrival with existing frames of the same priority into a single MAC sublayer access event.

Note: Grouping is the inclusion of more than one frame within a single media access event.

3.3.2.2.4.3.1.2.1 Frame Grouping

Frame grouping, if supported, shall be performed at the DLS sublayer using the MF bit of individual frames to indicate whether or not more frames are to follow. This facilitates ungrouping at the receive end. Frame grouping shall observe the following rules:

- The frame group shall not exceed the length indicated by the parameter N1, which is the maximum size of a frame group (including the frame headers of the individual frames).

- Frames of the same priority, regardless of acknowledged frames and unacknowledged frames, shall be grouped first. Grouping of higher priority with lower priority frames shall be permitted, provided the addition of lower priority frames can be accommodated without requiring additional bursts.

- With respect to frames requiring acknowledgement, only those with the same destination shall be grouped.

- The frame group shall be presented to the MAC sublayer in a single reservation for media access. A frame group shall be treated as a single entity with respect to acknowledgement. Only the acknowledged frames within a frame group shall be retransmitted upon T1 timer expiration. The unacknowledged frames shall be dropped upon completion of the transmission and shall not be retransmitted.

  Note: *The intention of allowing lower priority messages to be grouped is to allow otherwise wasted bandwidth to be used. This filling of excess space in a burst is not mandatory.*

3.3.2.2.4.3.2 Reception Acknowledgement

3.3.2.2.4.3.2.1 Acknowledged Frames

Discretely-addressed INFO and CTRL_RSP frames shall require acknowledgement of correct reception via the ACK frame. Upon correctly passing the FCS test of all frames requiring acknowledgement in a media access event (e.g., single frame or group), the DLS shall send a single ACK frame to the originator of the frame or group. If the FCS for any frame requiring acknowledgement in a media access event fails, all frames requiring acknowledgement (discretely-addressed INFO and CTRL_RSP frames) in the group shall be discarded.

Note: *The aircraft MAC sublayer will remove ACK frames from the queue and send the M downlink (Acknowledge) burst instead.*

3.3.2.2.4.3.2.2 Unacknowledged Frames

Broadcast INFO and all CTRL_CMD and ACK frames shall be unacknowledged. If any frame not requiring acknowledgement passes its FCS, then that frame should be processed.

3.3.2.2.4.3.3 Transmission Acknowledgement/Retransmission

The DLS shall not send a new frame group to the MAC sublayer until an acknowledgement frame has been received for the previous acknowledged frame group or upon expiration of the T1 timer.

When the T1 timer expires, the DLS shall provide the MAC sublayer with the same frame group, minus any unacknowledged frames, for retransmission.

> *Note: The Media Access Control sublayer is responsible for the determination of when to retransmit the message. The DLS must remain involved in the retransmission procedure as the MAC sublayer cannot acknowledge correct receipt of a message until the DLS declares the message to have passed the FCS test.*

~~3.3.2.2.4.3.3 Transmission Acknowledgement/Retransmission~~

~~The DLS shall not send a new frame group to the MAC sublayer until an acknowledgement frame has been received for the previous acknowledged frame group or upon expiration of the T1 timer. When the T1 timer expires, the DLS shall provide the MAC sublayer with a new frame group, based on the current priority queuing, for transmission.~~

> ~~*Note: The Media Access Control sublayer is responsible for the determination of when to retransmit the message. The DLS must remain involved in the retransmission procedure as the MAC sublayer cannot acknowledge correct receipt of a message until the DLS declares the message to have passed the FCS test.*~~

3.3.2.2.4.4 Control Frame

The CTRL frame shall be used for the LME to establish and maintain links as defined in Section 3.3.2.3. This frame's information field shall be formatted per Section 3.3.2.3.3.3.

3.3.2.2.4.4.1 Control Command Frame

The CTRL_CMD frame shall be used to send XID_CMD parameters. The correct receipt of a CTRL_CMD frame shall be acknowledged via a CTRL_RSP frame.

3.3.2.2.4.4.2 Control Response Frame

The CTRL_RSP frame shall be used to answer XID commands. The correct receipt of a CTRL_RSP frame shall be acknowledged via an ACK frame or ACK M burst as appropriate.

3.3.2.2.5 MAC-DLS Processing Delays

The maximum allowable processing delays required to ensure timely transmission of ACK frames and timely processing and delivery of ACK frames from DLS to MAC at both the ground station and aircraft are defined in the following subsections.

3.3.2.2.5.1 Aircraft DLS-MAC Processing Delay

The maximum processing delay allowable for the aircraft VDL to process an uplink ACK frame shall not exceed 200 ms under the worst case aircraft loading conditions. The uplink ACK processing delay shall be defined to start at the time that the aircraft MAC receives the uplink V/D (data) burst, which contains the uplink ACK, and to end after the uplink ACK is extracted by the aircraft DLS and is forwarded to and received by the aircraft MAC to cause the T1 timer to be cancelled.

3.3.2.2.5.2 Downlink ACK Transmission Delay

After receiving the last acknowledged uplink V/D (data) burst with an EOM indicator in the V/D (data) burst header, the receiving aircraft station shall generate and transmit an ACK in the downlink M channel slot that begins exactly one MAC cycle period after the beginning of the time slot containing the EOM indication. The aircraft shall not transmit the ACK in any other slots.

3.3.2.2.5.3 Uplink ACK Transmission Delay

The ground station MAC shall transmit the first uplink V/D (data) burst, which contains the uplink ACK frame, within T_ack MAC cycles after receipt of the last V/D (data) burst, where T_ack is a MAC data frame transmission system parameter defined in Section 3.3.2.1.4.5.

> Note: *To facilitate the ground station in meeting this requirement, one or more of the following measures may be required:*
>
> - *The ground station DLS always places the ACK frames at the head of a grouped frame so that the ACK frames will be transmitted in the first V/D (data) burst of an uplink data transmission.*
>
> - *The ground station should always transmit the uplink bursts with ACK frames at the earliest possible burst opportunity, i.e., the V/D (data) burst with ACK should be transmitted immediately if there is no outstanding data transmission or immediately after the outstanding data transmission is completed. Outstanding data transmission is defined to be a data transmission that is in progress or a data access that has been granted time slots for transmission.*
>
> - *The message type field in the message header of the downlink data bursts should be used as an advance notice that an uplink ACK will need to be transmitted in developing the ground station scheduling algorithm. With this advance information the ground scheduler can schedule the uplink or*

downlink data transmission to accommodate the uplink ACK transmission requirement.

- *The maximum processing delay allowable for the ground station to process a downlink data transmission to generate an uplink ACK frame may need to be limited to no more than 240 ms under the worst case loading condition. The processing delay is defined as from the time that the ground MAC receives the last V/D data burst of an acknowledged data message and ends with the ACK being generated by the ground station DLS, forwarded to, and received by the ground station MAC.*

3.3.2.2.5.4 Downlink Data Transmission Delay

After receiving a Reservation Response, the aircraft shall begin to transmit the V/D (data) bursts at the scheduled time slots in the next MAC cycle.

> Note: *The most stringent case for downlink data transmission delay would be for 3T configuration where transmission may be required to take place in 150 ms measured from the beginning of the time slot of the received Reservation Response.*

3.3.2.3 Link Management Entity (LME) Sublayer (VDL Mode 3)

3.3.2.3.1 Services

The LME sublayer shall provide link management and release services between local DLS and remote DLS. It shall deliver link status information to the subnetwork dependent convergent function (SNDCF), DLS, and voice unit.

3.3.2.3.2 Operation Procedures

The LME shall support:

- Link Establishment
- Slot Selection (Configurations 3S and 2S1X)
- Link Modification
- Recovery
- Link Release
- Handoff
- Authentication

3.3.2.3.2.1 Link Establishment

The VDL Mode 3 link establishment procedure shall consist of three phases:

- Net Initialization
- Net Entry
- Initial Link Negotiation

The following sections describe the operation of these phases.

3.3.2.3.2.1.1 Net Initialization

Before the link establishment procedure, the aircraft station shall initialize to initial timing state 0 (TS0) and set parameters CTC1, CTC2, and CTC3 to max (f-50, t). The aircraft station shall enter TS0 either at the end of the transmission of the Leaving Net message (for discrete-addressed operation) or upon receipt of a new tuning command at the radio (for non-discrete-addressed operation). The first part of the link establishment procedure shall be the acquisition of the M uplink burst (LBAC 11 for 3T configuration, LBAC 5, 7, or 9 for 3S configuration, LBAC 4 or 6 for 2S1X configuration, LBAC 9 for 1V3D configuration, LBAC 7 for 1V2D configuration and LBAC 5 for other configurations) associated with the specified user group identifier.

Upon receipt of 2 consecutive M uplink bursts containing identical information (i.e., System Configuration, Squelch Window, Slot ID, and Ground Station Code) in octets 1-3 of the M uplink burst, the LME shall declare the net initialized and shall establish the net operating parameters based on the static information contained in octets 1-3. In configurations 3S and 2S1X the LME shall declare the net initialized when at least one of the wide area coverage slots provides two consecutive M uplink bursts containing identical information in octets 1-3. Upon net initialization, the aircraft station shall transition from TS0 to TS1.

If the aircraft station is unable to enter TS1, it shall search for ATSs to determine the number of slots in its net and enter TS2. If CTC3 equals parameter f before the aircraft station enters TS2, it shall enter TS3. Prior to net initialization, voice access shall be inhibited.

Transition from TS0 to TS2 or TS3 shall be prohibited (see Section 3.3.2.1.4.1.2) if an ATS received from a ground station (i.e., an uplink beacon from a ground station operating in another time slot) contains system configuration information that indicates that the aircraft radio has incorrectly tuned to a data slot.

Note: Net Initialization is a prerequisite for the next step of Net Entry, however with Net Initialization only, basic voice services can be supported.

~~Before the link establishment procedure, the aircraft VDL shall initialize to initial timing state 0 (TS0) and set parameters CTC1, CTC2, and CTC3 to max(f-50, t). The first part of the link establishment procedure shall be the acquisition of the M uplink burst (LBAC 11 for 3T configuration, LBAC 5, 7, or 9 for 3S configuration, LBAC 4 or 6 for 2S1X, and LBAC 5 for other configurations) associated with the specified user group identifier. Upon receipt of 2 consecutive M uplink bursts containing identical information (i.e., System Configuration, Squelch Window, Slot ID, and Ground Station Code) in bits 5-8 of octet 2 and all of octet 3 of the uplink burst, the LME shall declare the net initialized and shall establish the net operating parameters based on the static information contained in bits 5-8 of octet 2 and all of octet 3. Configurations 3S and 2S1X shall be considered initialized when at least one of the wide area coverage slots provides consecutive M uplink bursts~~

~~containing identical information in bits 5-8 of octet 2 and all of octet 3. Upon net initialization, the aircraft VDL shall transition from TS0 to TS1.~~

~~If the aircraft VDL is unable to enter TS1, it shall search for ATSs to determine the number of slots in its net and enter TS2. If CTC3 equals parameter f before the aircraft VDL enters TS2, it shall enter TS3. Prior to net initialization, voice access shall be inhibited.~~

> ~~*Note: Net Initialization is a prerequisite for the next step of Net Entry, however with Net Initialization only, dedicated voice circuits (Section 3.3.5) can be supported.*~~

3.3.2.3.2.1.2 Net Entry

The net entry procedure shall begin with the aircraft station transmitting a Net Entry Request message following the successful net initialization. The transmission of the Net Entry Request message and the subsequent retransmission, if enabled, shall follow the procedures described in Appendix I. The Net Entry retransmission shall continue until a Net Entry Response message is received or the number of retransmissions reaches NL1. After NL1 retries (Table 3-66a), the SN-SME shall be notified. If a Net Entry Response message is received, the aircraft station shall transmit a Poll Response message in the next MAC cycle. If the Net Entry Response message is of type "previous link preserved," the aircraft TL3 timer (Table 3-66a) shall be stopped.

> *Note 1: All configurations that offer one or more data circuit(s) must support net entry (3V1D, 2V2D, 2V1D, 1V3D, 1V2D, 3T). The voice only configurations (3V, 4V, 3S, and 2S1X) may support net entry if discrete addressing is enabled by the ground user.*

Upon receiving a Net Entry Request message, the ground shall check the aircraft ICAO address. If this address has been assigned a Local ID and the TL3 timer has not been started, the ground shall transmit the Net Entry Response message of type "previous link preserved." When the Poll Response message is received by the ground station, the ground station shall respond by sending a Reservation Response, contained within a Supported Options message, to the entering aircraft during the next MAC cycle. This response shall be either a reservation or a RACK if data slots were requested or a "no reservation" indication if no data slots were requested.

If the aircraft ICAO address has not been assigned a Local ID, the ground shall assign the next available Local User ID to the requesting aircraft and the pending disconnect link table shall be examined. If the aircraft ICAO address is found in the table, the link status shall be reinstated, the TL3 timer shall be stopped, and the link port address shall be changed to the new radio station port address. The ground shall transmit the Net Entry Response message of type "previous link preserved." When the Poll Response message is received by the ground station, the ground station shall respond by sending a Reservation Response, contained within a Supported Options message, to the entering aircraft during the next MAC cycle. This response shall be either a reservation or a RACK if data slots were requested or a "no reservation" indication if no data slots were requested.

If the aircraft ICAO address is not found in the table and a Local ID has been assigned, the ground shall transmit a Net Entry Response message of type "no previous link." When the Poll Response message is received by the ground station, the ground station shall respond by sending a Reservation Response, contained within a Supported Options message, to the entering aircraft during the next MAC cycle. This response shall be either a reservation or a RACK if data slots were requested or a "no reservation" indication if no data slots were requested. If an aircraft receives a Net Entry Response message of type "no previous link", it also shall form a join event message, as required by the supported network stack and deliver it to the air router.

If there are already 60 aircraft in the net when the Net Entry Request message is received, the ground LME shall respond with a Net Entry Response message with the local identifier field set to 0, indicating that the net is currently full. The aircraft radio shall then use a Local ID of 61 when communicating with the ground station and other aircraft to indicate that it has not entered the net. When an aircraft radio is in this state, it shall continue to monitor all Net Entry Response messages in order to detect a delayed Net Entry Response message addressed to it via its aircraft ICAO number. Upon receipt of such a message, the aircraft radio shall change its Local ID to the value provided.

Note 2: There is no limit on how many aircraft can use the aircraft ID of 61 simultaneously.

If a duplicate Net Entry Request message is received it shall be discarded.

If the requesting aircraft does not receive a Reservation message from the ground in the next MAC cycle after transmitting the Poll Response message, it shall restart the net entry procedure.

Note 3: The GNI provides a connection management function across multiple ground stations such that the same subnetwork connections are maintained with aircraft served by those ground stations. A description of the GNI function is provided in the ICAO Implementation Aspects for VDL Mode 3.

Note 4: A Net Entry Request message is considered to be a duplicate if a ground station receives a retransmitted Net Entry Request while it is still processing a *previously received Net Entry Request from the same aircraft.*

Note 5: Aircraft radios receiving a "Full Net" indication in the Net Entry Response message cannot avail themselves of services requiring discrete addressing until a valid Local ID is provided via the delayed net entry process. From that point forward the aircraft radio can participate in all discrete-addressed services it can support. For example, data-capable radios can begin link negotiation via XIDs at this time.

Note 6: In order to provide a delayed net entry capability, the ground station must maintain a time ordered list of potential net entrants. As they become available due to aircraft leaving the net, Local ID numbers should be distributed to waiting aircraft radios on a first-come-first-served basis.

~~The net entry procedure shall begin with the aircraft station transmitting a Net Entry Request message following the successful net initialization. The transmission of the Net Entry Request message and the subsequent retransmission, if enabled, shall follow the procedures described in Appendix I. The Net Entry retransmission shall continue until a Net Entry Response message is received or the number of retransmissions reaches NL1. After NL1 retries (Table 3-66a), the SN-SME shall be notified. If a Net Entry Response message is received, the aircraft station shall transmit a Poll Response message in the next MAC cycle. If the Net Entry Response message is of type "previous link preserved," the aircraft TL3 timer (Table 3-66a) shall be stopped.~~

~~*Note 1: All configurations that offer one or more data circuit(s) must support net entry (3V1D, 2V2D, 2V1D, 3T). The voice only configurations (3V, 4V, 3S, and 2S1X) may support net entry if discrete addressing is enabled by the ground user.*~~

~~Upon receiving a Net Entry Request message, the ground shall check the aircraft ICAO address. If this address has been assigned a Local ID and the TL3 timer has not been started, the ground shall transmit the Net Entry Response message of type "previous link preserved." When the Poll Response message is received by the ground station, the ground station shall respond by sending a Reservation Response message to the entering aircraft during the next MAC cycle. This message shall be either a reservation or a RACK if data slots were requested or a "no reservation" message if no data slots were requested.~~

~~If the aircraft ICAO address has not been assigned a Local ID, the ground shall assign the next available Local User ID to the requesting aircraft and the pending disconnect link table shall be examined. If the aircraft ICAO address is found in the table, the link status shall be reinstated, the TL3 timer shall be stopped, and the link port address shall be changed to the new radio station port address. The ground shall transmit the Net Entry Response message of type "previous link preserved." When the Poll Response message is received by the ground~~

~~station, the ground station shall respond by sending a Reservation Response message to the entering aircraft during the next MAC cycle. This message shall be either a reservation or a RACK if data slots were requested or a "no reservation" message if no data slots were requested.~~

~~If the aircraft ICAO address is not found in the table and a Local ID has been assigned, the ground shall transmit the Net Entry Response message of type "no previous link." When the Poll Response message is received by the ground station, the ground station shall respond by sending a Reservation Response message to the entering aircraft during the next MAC cycle. This message shall be either a reservation or a RACK if data slots were requested or a "no reservation" message if no data slots were requested. If an aircraft receives a Net Entry Response message of type "no previous link", it also shall form a join event message, as required by the supported network stack and deliver it to the air router.~~

~~If there are already 60 aircraft in the net when the Net Entry Request message is received, the ground LME shall respond with a Net Entry Response message with the local identifier field set to 0 indicating that the net is currently full. The aircraft shall then use a Local ID of 61 to indicate that it has not entered the net, when communicating with the ground station and other aircraft.~~

~~Note 2: There is no limit on how many aircraft can use the aircraft ID of 61 simultaneously.~~

~~If a duplicate Net Entry Request message is received it shall be discarded.~~

~~If the requesting aircraft does not receive a Reservation message from the ground in the next MAC cycle after transmitting the Poll Response message, it shall restart the net entry procedure.~~

~~Notes:~~

~~3. The GNI provides a connection management function across multiple ground stations such that the same subnetwork connections are maintained with aircraft served by those ground stations. A description of the GNI function is provided in the ICAO Implementation Aspects for VDL Mode 3.~~

~~4. A Net Entry Request message is considered to be a duplicate if a ground station receives a retransmitted Net Entry Request while it is still processing a previously received Net Entry Request from the same aircraft.~~

~~5. Aircraft receiving a "Net Full" indication in the Net Entry Response message are expected to operate in a limited manner until the pilot manually directs the LME to re-initiate the Net Entry Process.~~

~~3.3.2.3.2.1.2 Net Entry~~

~~The net entry procedure shall begin with the aircraft station transmitting a Net Entry Request message following the successful net initialization. The transmission of the Net Entry Request message and the subsequent retransmission, if enabled, shall follow the procedures described in Appendix I. The Net Entry retransmission shall continue until a Net Entry Response message is received or the number of retransmissions reaches NL1. After NL1 retries (Table 3-66a), the SN-SME shall be notified. If a Net Entry Response message is received, the aircraft station shall transmit a Poll Response message in the next MAC cycle. If the~~

~~Net Entry Response message is of type "previous link preserved," the aircraft TL3 timer (Table 3-66a) shall be stopped.~~

> ~~*Note:*~~ ~~*All configurations that offer one or more data circuit(s) must support net entry (3V1D, 2V2D, 2V1D, 3T). The voice only configurations (3V, 4V, 3S, and 2S1X) may support net entry if discrete addressing is enabled by the ground user.*~~

~~Upon receiving a Net Entry Request message, the ground shall check the aircraft ICAO number. If this number has been assigned a Local ID and the TL3 timer has not been started, the ground shall transmit the Net Entry Response message of type "previous link preserved." When the Poll Response message is received by the ground station, the ground station shall respond by sending a Reservation Response message to the entering aircraft during the next MAC cycle. This message shall be either a reservation or a RACK if data slots were requested or a "no reservation" message if no data slots were requested.~~

~~If the aircraft ICAO number has not been assigned a Local ID, the ground shall assign the next available Local User ID to the requesting aircraft and the pending disconnect link table shall be examined. If the aircraft ICAO number is found in the table, the link status shall be reinstated, the TL3 timer shall be stopped, and the link port address shall be changed to the new radio station port address. The ground shall transmit the Net Entry Response message of type "previous link preserved." When the Poll Response message is received by the ground station, the ground station shall respond by sending a Reservation Response message to the entering aircraft during the next MAC cycle. This message shall be either a reservation or a RACK if data slots were requested or a "no reservation" message if no data slots were requested.~~

~~If the aircraft ICAO number is not found in the table and a Local ID has been assigned, the ground shall transmit the Net Entry Response message of type "no previous link." When the Poll Response message is received by the ground station, the ground station shall respond by sending a Reservation Response message to the entering aircraft during the next MAC cycle. This message shall be either a reservation or a RACK if data slots were requested or a "no reservation" message if no data slots were requested. It also shall form a join event message, as required by the supported network stack and deliver it to all ground routers which are directly connected to the local ground network interface (GNI).~~

~~If there are already 60 aircraft in the net when the Net Entry Request message is received, the ground LME shall respond with a Net Entry Response message with the local identifier field set to 0 indicating that the net is currently full. The aircraft shall then use a Local ID of 61 to indicate that it has not entered the net, when communicating with the ground station and other aircraft.~~

~~If a duplicate Net Entry Request message is received it shall be discarded.~~

~~If the requesting aircraft does not receive a Reservation message from the ground in the next MAC cycle after transmitting the Poll Response message, it shall restart the net entry procedure.~~

~~*Notes:*~~

~~*1: The GNI provides a connection management function across multiple ground stations such that the same subnetwork connections are maintained with aircraft served by those ground stations. A description of the GNI function is provided in the ICAO Implementation Aspects for VDL Mode 3.*~~

~~*2. A Net Entry Request message is considered to be a duplicate if a ground station receives a retransmitted Net Entry Request while it is still processing a previously received Net Entry Request from the same aircraft.*~~

~~*3. Aircraft receiving a "Net Full" indication in the Net Entry Response message are expected to operate in a limited manner until the pilot manually directs the LME to re-initiate the Net Entry Process.*~~

3.3.2.3.2.1.2.1 Supported Options

The final uplink in the net entry process includes the Supported Option message. The aircraft LME shall enable or disable the options indicated in the message. The options shall be as defined in **Table G-9**.

3.3.2.3.2.1.3 Initial Link Negotiation

Following Net Entry, the aircraft LME shall initiate the link negotiation phase of link establishment to configure the link. The configuration shall be negotiated using Exchange Identifiers (XIDs) specified in Table 3-65a according to the procedures described in the subsections below. The parameters negotiated shall be in effect for the duration of the connection. If the link is preserved between ground stations, then the parameter states are maintained as well, subject to later negotiation.

Note: VDL Mode 3 uses the CTRL_CMD frame in a similar manner as the VDL Mode 2 uses an XID frame with the C/R bit set to Command. Likewise, the CTRL_RSP frame is used similar to the VDL Mode 2 XID frame with the C/R bit set to Response

3.3.2.3.2.1.3.1 Air Initiation

When commanded, the aircraft LME shall attempt to configure the link with a ground station by sending a CTRL_CMD_LE frame with parameters per Table 3-65a. The optional parameters shall be included if a non-default value is desired. This message must indicate at least one network type to be supported in the Network Initialization XID.

3.3.2.3.2.1.3.2 General Ground Response

If the ground LME receives the CTRL_CMD_LE, frame it shall confirm link configuration by sending a CTRL_RSP_LE frame containing the parameters from the CTRL_CMD_LE that are accepted as well as any that are modified from those included.

3.3.2.3.2.1.3.3 Air Response

If the aircraft LME receives the CTRL_RSP_LE, it shall confirm receipt via an Acknowledgement M~~-~~ burst.

3.3.2.3.2.1.3.4 Exceptional Cases

3.3.2.3.2.1.3.4.1 Parameter Negotiation

If the ground LME cannot accommodate a requested non-default parameter setting, it shall include the value it can accept in the response. If no value is acceptable, the ground LME receiving the CTRL_CMD_LE cannot establish the link with the aircraft LME at this time and shall transmit a CTRL_RSP_LCR instead of a CTRL_RSP_LE, per Table 3-65a.

3.3.2.3.2.1.3.4.2 Unacceptable Parameters

If the parameters in the CTRL_RSP_LE from the ground LME are not acceptable to the aircraft LME, then the aircraft LME shall send a CTRL_RSP_LCR frame and terminate the data link connection.

Note: The CTRL_RSP_LCR frame will terminate the data link connection, but the aircraft radio will retain its Local ID number. It will then be able to continue participating in Enhanced Voice functions. There is no point to the radio reattempting Net Entry to this ground station, as it will continue to fail to establish the connection.

~~If the parameters in the CTRL_RSP_LE from the ground LME are not acceptable to the aircraft LME, then the aircraft LME shall notify the MAC to send a Leaving Net M burst to terminate the link, and then reset to an Aircraft Identifier of 61 to indicate the lack of discrete-addressed services.~~

3.3.2.3.2.1.3.4.3 Incorrect Response

While waiting for a response to a CTRL_CMD_LE, an aircraft LME receiving any unicast frame other than a CTRL_RSP shall retransmit the CTRL_CMD_LE.

3.3.2.3.2.1.3.4.4 Command Retransmission

Upon expiration of the T3 timer (Section 3.3.2.2.3.1) without receipt of a CTRL_RSP_LE frame, the LME shall retransmit the CTRL_CMD_LE frame.

3.3.2.3.2.1.3.4.5 Response Retransmission

The CTRL_RSP retransmission shall operate as any other directed data transfer. Upon expiration of the T1 timer (Section 3.3.2.3.3.3.1.2.2), the LME shall retransmit the CTRL_RSP_LE frame.

3.3.2.3.2.2 Slot Selection (Configurations 3S and 2S1X)

Configurations 3S and 2S1X shall employ a slot selection algorithm in the aircraft receiver which will choose the best slot to use for the processing of uplink Management frames and the forwarding of any uplink V/D (voice) frames to the voice unit. Slot selection shall be achieved by applying the selection algorithm to the M uplink bursts of all slots received during one or a number of MAC cycles.

In the downlink direction, the aircraft radio shall always transmit in slot A. For this reason the aircraft radio need not apply a slot selection algorithm in order to receive downlink V/D (voice) frames.

Table 3-65a: XID Parameters

			Air initiated Link establishment		Link connection rejection
	Source		Aircraft	New ground Station	Any station
	Destination		Proposed ground station	Aircraft	Any station
XID parameters	GI	PI	CTRL_CMD_LE	CTRL_RSP_LE	CTRL_RSP_LCR CTRL_CMD_LCR
Public parameters (8885:1993:Mode 3)					
Parameter set ID	80h	01h	N/A	O	N/A
N1-downlink	80h	05h	N/A	O	N/A
N1-uplink	80h	06h	N/A	O	N/A
Counter N2	80h	0Ah	N/A	O	N/A
Timer T1	80h	09h	N/A	O	N/A
Timer T-ack	80h	08h	N/A	O	N/A
Private parameters (V)					
Parameter set ID	F0h	00h	O	O	M
SQP	F0h	02h	O	O	N/A
LCR cause	F0h	06h	N/A	N/A	M
Modulation support	F0h	81h	O	N/A	N/A
Private parameters (W)					
Parameter set ID	F0h	00h	M	M	O
Algorithm version number	F0h	01h	O	O	O
Network initialization	F0h	02h	M	M	N/A
Connection check	F0h	03h	N/A	N/A	N/A
Version	F0h	04h	O	O	O
Authentication	F0h	05h	O	O	O

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Subnetwork User Data	F0h	06h	O	O	O
Assigned Altitude	F0h	07h	O	O	O
NM1	F0h	42h	N/A	O	N/A
RR	F0h	43h	N/A	O	N/A
WR	F0h	44h	N/A	O	N/A
RE	F0h	46h	N/A	O	N/A
RL	F0h	47h	N/A	O	N/A
Timer T3	F0h	48h	N/A	O	N/A
NL1	F0h	49h	N/A	O	N/A
Timer TL3	F0h	4Ah	N/A	O	N/A
Timer TL4	F0h	4Bh	N/A	O	N/A
WE	F0h	4Ch	N/A	O	N/A
Operative_GNI$_p$	F0h	4Fh	O	O	N/A
Aircraft_TMbB	F0h	50h	O	O	N/A
MbB_Operations_Permitted	F0h	51h	O	O	N/A
Expedited recovery	F0h	80h	O	N/A	N/A
t	F0h	81h	O	N/A	N/A
f	F0h	82h	O	N/A	N/A
Former_GNI$_p$	F0h	83h	O	O	N/A
Counter NL2	F0h	C1h	N/A	O	N/A

Key Abbreviations used for Table 3-65a above:

GI = ISO 8885 Group Identifier

PI = ISO 8885 Parameter Identifier

M = Mandatory

O = Optional

N/A = Not applicable

h = hexadecimal

~~Table 3-65a. XID Parameters~~

			~~Air initiated Link establishment~~		~~Link connection rejection~~
	~~Source~~		~~Aircraft~~	~~New ground Station~~	~~Any station~~
	~~Destination~~		~~Proposed ground station~~	~~Aircraft~~	~~Any station~~
~~XID parameters~~	~~GI~~	~~PI~~	~~CTRL_CMD_LE~~	~~CTRL_RSP_LE~~	~~CTRL_RSP_LCR~~ ~~CTRL_CMD_LCR~~
~~Public parameters (8885:1993:Mode 3)~~					
~~Parameter set ID~~	~~80h~~	~~01h~~	~~N/A~~	~~O~~	~~N/A~~
~~N1-downlink~~	~~80h~~	~~05h~~	~~N/A~~	~~O~~	~~N/A~~
~~N1-uplink~~	~~80h~~	~~06h~~	~~N/A~~	~~O~~	~~N/A~~
~~Counter N2~~	~~80h~~	~~0Ah~~	~~N/A~~	~~O~~	~~N/A~~
~~Timer T1~~	~~80h~~	~~09h~~	~~N/A~~	~~O~~	~~N/A~~
~~T-ack~~	~~80h~~	~~08h~~	~~N/A~~	~~0~~	~~N/A~~
~~Private parameters (V)~~					
~~Parameter set ID~~	~~F0h~~	~~00h~~	~~O~~	~~O~~	~~M~~
~~SQP~~	~~F0h~~	~~02h~~	~~O~~	~~O~~	~~N/A~~
~~LCR cause~~	~~F0h~~	~~06h~~	~~N/A~~	~~N/A~~	~~M~~
~~Modulation support~~	~~F0h~~	~~81h~~	~~O~~	~~N/A~~	~~N/A~~
~~Private parameters (W)~~					
~~Parameter set ID~~	~~F0h~~	~~00h~~	~~M~~	~~M~~	~~O~~
~~Algorithm version number~~	~~F0h~~	~~01h~~	~~O~~	~~O~~	~~O~~
~~Network initialization~~	~~F0h~~	~~02h~~	~~M~~	~~M~~	~~N/A~~
~~Connection check~~	~~F0h~~	~~03h~~	~~N/A~~	~~N/A~~	~~N/A~~
~~Version~~	~~F0h~~	~~04h~~	~~O~~	~~O~~	~~O~~
~~Authentication~~	~~F0h~~	~~05h~~	~~O~~	~~O~~	~~O~~
~~Subnetwork User Data~~	~~F0h~~	~~06h~~	~~O~~	~~O~~	~~O~~
~~NM1~~	~~F0h~~	~~42h~~	~~N/A~~	~~O~~	~~N/A~~
~~RR~~	~~F0h~~	~~43h~~	~~N/A~~	~~O~~	~~N/A~~
~~WR~~	~~F0h~~	~~44h~~	~~N/A~~	~~O~~	~~N/A~~
~~RE~~	~~F0h~~	~~46h~~	~~N/A~~	~~O~~	~~N/A~~
~~RL~~	~~F0h~~	~~47h~~	~~N/A~~	~~O~~	~~N/A~~
~~Timer T3~~	~~F0h~~	~~48h~~	~~N/A~~	~~O~~	~~N/A~~
~~NL1~~	~~F0h~~	~~49h~~	~~N/A~~	~~O~~	~~N/A~~
~~Timer TL3~~	~~F0h~~	~~4Ah~~	~~N/A~~	~~O~~	~~N/A~~
~~Timer TL4~~	~~F0h~~	~~4Bh~~	~~N/A~~	~~O~~	~~N/A~~
~~WE~~	~~F0h~~	~~4Ch~~	~~N/A~~	~~O~~	~~N/A~~
~~Operative_GNI$_p$~~	~~F0h~~	~~4Fh~~	~~O~~	~~O~~	~~N/A~~
~~Aircraft_TMbB~~	~~F0h~~	~~50h~~	~~O~~	~~O~~	~~N/A~~
~~MbB_Operations_Permitted~~	~~F0h~~	~~51h~~	~~O~~	~~O~~	~~N/A~~
~~Expedited recovery~~	~~F0h~~	~~80h~~	~~O~~	~~N/A~~	~~N/A~~
~~t~~	~~F0h~~	~~81h~~	~~O~~	~~N/A~~	~~N/A~~
~~f~~	~~F0h~~	~~82h~~	~~O~~	~~N/A~~	~~N/A~~
~~Former_GNI$_p$~~	~~F0h~~	~~83h~~	~~O~~	~~O~~	~~N/A~~
~~Counter NL2~~	~~F0h~~	~~C1h~~	~~N/A~~	~~O~~	~~N/A~~

~~Table 3-65a: XID Parameters~~

			~~**Air initiated Link establishment**~~		~~**Link connection rejection**~~
	~~**Source**~~		~~Aircraft~~	~~New ground Station~~	~~Any station~~
	~~**Destination**~~		~~Proposed ground station~~	~~Aircraft~~	~~Any station~~
~~**XID parameters**~~	~~**GI**~~	~~**PI**~~	~~**CTRL_CMD_LE**~~	~~**CTRL_RSP_LE**~~	~~**CTRL_RSP_LCR**~~ ~~**CTRL_CMD_LCR**~~
~~**Public parameters (8885:1993:Mode 3)**~~					
~~Parameter set ID~~	~~80h~~	~~01h~~	~~N/A~~	~~O~~	~~N/A~~
~~N1 downlink~~	~~80h~~	~~05h~~	~~N/A~~	~~O~~	~~N/A~~
~~N1 uplink~~	~~80h~~	~~06h~~	~~N/A~~	~~O~~	~~N/A~~
~~Counter N2~~	~~80h~~	~~0Ah~~	~~N/A~~	~~O~~	~~N/A~~
~~Timer T1~~	~~80h~~	~~09h~~	~~N/A~~	~~O~~	~~N/A~~
~~**Private parameters (V)**~~					
~~Parameter set ID~~	~~F0h~~	~~00h~~	~~O~~	~~O~~	~~M~~
~~SQP~~	~~F0h~~	~~02h~~	~~O~~	~~O~~	~~N/A~~
~~LCR cause~~	~~F0h~~	~~06h~~	~~N/A~~	~~N/A~~	~~M~~
~~Modulation support~~	~~F0h~~	~~81h~~	~~O~~	~~N/A~~	~~N/A~~
~~**Private parameters (W)**~~					
~~Parameter set ID~~	~~F0h~~	~~00h~~	~~M~~	~~M~~	~~O~~
~~Algorithm version number~~	~~F0h~~	~~01h~~	~~O~~	~~O~~	~~O~~
~~Network initialization~~	~~F0h~~	~~02h~~	~~M~~	~~M~~	~~N/A~~
~~Connection check~~	~~F0h~~	~~03h~~	~~N/A~~	~~N/A~~	~~N/A~~
~~Version~~	~~F0h~~	~~04h~~	~~O~~	~~O~~	~~O~~
~~Authentication~~	~~F0h~~	~~05h~~	~~O~~	~~O~~	~~O~~
~~NM1~~	~~F0h~~	~~42h~~	~~N/A~~	~~O~~	~~N/A~~
~~RR~~	~~F0h~~	~~43h~~	~~N/A~~	~~O~~	~~N/A~~
~~WR~~	~~F0h~~	~~44h~~	~~N/A~~	~~O~~	~~N/A~~
~~RE~~	~~F0h~~	~~46h~~	~~N/A~~	~~O~~	~~N/A~~
~~RL~~	~~F0h~~	~~47h~~	~~N/A~~	~~O~~	~~N/A~~
~~Timer T3~~	~~F0h~~	~~48h~~	~~N/A~~	~~O~~	~~N/A~~
~~NL1~~	~~F0h~~	~~49h~~	~~N/A~~	~~O~~	~~N/A~~
~~Timer TL3~~	~~F0h~~	~~4Ah~~	~~N/A~~	~~O~~	~~N/A~~
~~Timer TL4~~	~~F0h~~	~~4Bh~~	~~N/A~~	~~O~~	~~N/A~~
~~WE~~	~~F0h~~	~~4Ch~~	~~N/A~~	~~O~~	~~N/A~~
~~Operative_GNI$_p$~~	~~F0h~~	~~4Fh~~	~~O~~	~~O~~	~~N/A~~
~~Aircraft_TMbB~~	~~F0h~~	~~50h~~	~~O~~	~~O~~	~~N/A~~
~~MbB_Operations_Permitted~~	~~F0h~~	~~51h~~	~~O~~	~~O~~	~~N/A~~
~~CT1~~	~~F0h~~	~~52h~~	~~O~~	~~O~~	~~O~~
~~Timer CT2~~	~~F0h~~	~~53h~~	~~O~~	~~O~~	~~O~~
~~Timer CT3~~	~~F0h~~	~~54h~~	~~O~~	~~O~~	~~O~~
~~GDTE~~	~~F0h~~	~~55h~~	~~N/A~~	~~O~~	~~N/A~~
~~VER~~	~~F0h~~	~~56h~~	~~O~~	~~O~~	~~O~~
~~M-BIT~~	~~F0h~~	~~57h~~	~~O~~	~~O~~	~~O~~
~~Expedited recovery~~	~~F0h~~	~~80h~~	~~O~~	~~N/A~~	~~N/A~~
~~t~~	~~F0h~~	~~81h~~	~~O~~	~~N/A~~	~~N/A~~
~~f~~	~~F0h~~	~~82h~~	~~O~~	~~N/A~~	~~N/A~~
~~Former_GNI$_p$~~	~~F0h~~	~~83h~~	~~O~~	~~O~~	~~N/A~~
~~ADSA~~	~~F0h~~	~~84h~~	~~O~~	~~N/A~~	~~N/A~~
~~Counter NL2~~	~~F0h~~	~~C1h~~	~~N/A~~	~~O~~	~~N/A~~

Key for Table 3-65a above:

Abbreviations used: GI = ISO 8885 Group Identifier O = Optional M = Mandatory

PI = ISO 8885 Parameter Identifier N/A = Not applicable h = hexadecimal

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> *Note: Details of selection algorithms that could be used by the aircraft radio are described in the ICAO Implementation Aspects for VDL Mode 3.*

3.3.2.3.2.3 Link Modification

3.3.2.3.2.3.1 Description of LME Procedures

The aircraft and ground LMEs shall use the CTRL_CMD and CTRL_RSP frame types listed in Table 3-65b and the procedures described in the text below to maintain a reliable connection between the aircraft and ground system. The parameters negotiated shall be in effect for the duration of the link connection.

> *Note: VDL Mode 3 uses the CTRL_CMD frame in a similar manner as VDL Mode 2 uses an XID frame with the C/R bit set to Command. Likewise, the CTRL_RSP frame is used similar to the VDL Mode 2 XID frame with the C/R bit set to Response.*

3.3.2.3.2.3.2 Link Maintenance Procedures

The aircraft and ground LME shall be capable of using the following procedures to maintain connectivity across the VHF link.

a) Addressed link parameter modification
b) Broadcast link parameter modification

3.3.2.3.2.3.2.1 Addressed Link Parameter Modification

3.3.2.3.2.3.2.1.1 Ground Initiation

The ground LME shall request a modification of parameters of a link by sending a CTRL_CMD_LPM to the aircraft LME containing the parameters per Table 3-65b.

3.3.2.3.2.3.2.1.2 General Aircraft Response

The aircraft LME shall acknowledge with a CTRL_RSP_LPM containing the parameters per Table 3-65b.

3.3.2.3.2.3.2.1.3 Ground Acknowledgment

The ground LME shall acknowledge the correct receipt of the CTRL_RSP_LPM via the ACK frame.

3.3.2.3.2.3.2.2 Broadcast Link Parameter Modification

3.3.2.3.2.3.2.2.1 Ground Initiation

The ground LME shall request a modification of parameters of all links by sending to all aircraft LMEs in the specified user group a broadcast-addressed CTRL_CMD_LPM containing the parameters per Table 3-65b.

3.3.2.3.2.3.2.2.2 General Aircraft Response

The aircraft LME shall not respond to broadcast CTRL_CMD_LPM frames.

> Note: *As there is no acknowledgement to broadcast CTRL frames, the ground station operator may transmit the frames multiple times to increase the likelihood of correct reception.*

3.3.2.3.2.4 Link Maintenance

The ground LME shall periodically poll each aircraft participating in the net using the Poll Request message, no more frequently than once per 6 seconds. If the ground LME receives a Poll Response message it shall reset the Polling Reply Counter (NL2) to 0. Otherwise, the ground LME shall increment the Polling Reply Counter.

Upon receipt of a Poll Request message, the aircraft LME shall reset the Polling Interval parameter (TL4). If the aircraft LME has received a Next Net message it shall issue a Next Net Acknowledgment message to the MAC sublayer. Otherwise, the aircraft LME shall issue a Poll Response message to the MAC sublayer.

~~The ground LME shall periodically poll each aircraft participating in the net using the Poll Request message. If the ground LME receives a Poll Response message it shall reset the Polling Reply Counter (NL2) to 0. Otherwise, the ground LME shall increment the Polling Reply Counter.~~

~~Upon receipt of a Poll Request message, the aircraft LME shall reset the Polling Interval parameter (TL4). If the aircraft LME has received a Next Net message it shall issue a Next Net Acknowledgment message to the MAC sublayer. Otherwise, the aircraft LME shall issue a Poll Response message to the MAC sublayer.~~

3.3.2.3.2.5 Recovery

The recovery procedure shall be initiated when either the ground or aircraft protocol stack has lost state information needed to communicate.

If an aircraft loses protocol state information, it shall send a CTRL_RSP frame with LCR Cause XID indicating an appropriate code, when possible, followed by the aircraft attempting to do part or all of the Link Establishment procedures per Section 3.3.2.3.2.1, whatever is necessary to re-establish the link with the ground station.

Notes:

1. *An example of the VDL Mode 3 protocol states and state transitions is given in Section 13 of the ICAO VDL Mode 3 Implementation Manual.*
2. *Depending on the extent of the loss of the protocol state information, the aircraft station may or may not be capable of sending a CTRL_RSP frame. For example, if only the DLS protocol state information is lost it may be necessary for the aircraft station to do only Link Negotiation, bypassing Net Initialization and Net Entry, in order to re-establish the link with the ground station.*

After the ground begins recovery, it shall broadcast a Recovery message to instruct all aircraft to enter into the same condition. Both the ground and aircraft stations shall undertake recovery procedures until connections are re-established with all responding aircraft. While in the recovery procedure, the ground station shall attempt to sequentially contact each possible aircraft identifier to determine which identifiers are in use.

3. The recovery procedure allows the normal net entry process to be bypassed to re-establish contact with aircraft that are still in the ground station coverage area when the recovery procedure is invoked.

~~The recovery procedure shall be initiated when the ground protocol stack has lost state information needed to communicate with aircraft. Both the ground and aircraft VDL shall operate in the recovery mode until connections are re-established with all responding aircraft. If an aircraft loses protocol state information, it shall send a CTRL_RSP frame with LCR Cause XID indicating an appropriate code followed by the aircraft attempting the Link Connection procedures per Section 3.3.2.3.2.1.~~

~~After the ground enters into recovery state, it shall broadcast a Recovery message to instruct all aircraft to enter into the same state. While in the recovery state, the ground station shall attempt to sequentially contact each possible aircraft identifier to determine which are in use.~~

~~*Note: The recovery procedure allows the normal net entry process to be bypassed to re-establish contact with*~~

Table 3-65b: XID Parameters

			Addressed link parameter modification		Broadcast link parameter modification
	Source		Current ground station	Aircraft	Current ground station
	Destination		Aircraft	Current ground Station	Aircraft
XID parameters	GI	PI	CTRL_CMD_LPM	CTRL_RSP_LPM	CTRL_CMD_LPM (GSIF)
Public parameters (8885:1993: Mode 3)					
Parameter set ID	80h	01h	O	N/A	O
N1-downlink	80h	05h	O	N/A	O
N1-uplink	80h	06h	O	N/A	O
Counter N2	80h	0Ah	O	N/A	O
Timer T1	80h	09h	O	N/A	O
Timer T-ack	80h	08h	N/A	O	N/A
Private parameters (V)					
Parameter set ID	F0h	00h	O	O	O
SQP	F0h	02h	O	O	O
LCR cause	F0h	06h	N/A	N/A	N/A
Modulation support	F0h	81h	N/A	N/A	N/A
Private parameters (W)					
Parameter set ID	F0h	00h	O	O	O
Algorithm version number	F0h	01h	O	N/A	O
Network initialization	F0h	02h	O	O	O
Connection check	F0h	03h	O	O	O
Version	F0h	04h	N/A	N/A	O
Authentication	F0h	05h	O	O	O

Subnetwork User Data	F0h	06h	O	O	O	
Assigned Altitude	F0h	07h	O	O	O	
NM1	F0h	42h	O	N/A	O	
RR	F0h	43h	O	N/A	O	
WR	F0h	44h	O	N/A	O	
RE	F0h	46h	O	N/A	O	
RL	F0h	47h	O	N/A	O	
Timer T3	F0h	48h	O	N/A	O	
NL1	F0h	49h	O	N/A	O	
Timer TL3	F0h	4Ah	O	N/A	O	
Timer TL4	F0h	4Bh	O	N/A	O	
WE	F0h	4Ch	O	N/A	O	
Operative_GNI$_p$	F0h	4Fh	O	O	O	
Aircraft_TMbB	F0h	50h	O	O	O	
MbB_Operations_Permitted	F0h	51h	O	O	O	
Expedited recovery	F0h	80h	N/A	N/A	N/A	
t	F0h	81h	O	N/A	O	
f	F0h	82h	O	N/A	O	
Former_GNI$_p$	F0h	83h	O	O	O	
Counter NL2	F0h	C1h	O	N/A	O	

Key Abbreviations used for Table 3-65b above:

GI = ISO 8885 Group Identifier

PI = ISO 8885 Parameter Identifier

M = Mandatory

O = Optional

N/A = Not applicable

h = hexadecimal

~~Table 3-65b. XID Parameters~~

			~~Addressed link parameter modification~~		~~Broadcast link parameter modification~~
	~~Source~~		~~Current ground station~~	~~Aircraft~~	~~Current ground station~~
	~~Destination~~		~~Aircraft~~	~~Current ground Station~~	~~Aircraft~~
~~XID parameters~~	~~GI~~	~~PI~~	~~CTRL_CMD_LPM~~	~~CTRL_RSP_LPM~~	~~CTRL_CMD_LPM (GSIF)~~
~~Public parameters (8885:1993:Mode3)~~					
~~Parameter set ID~~	~~80h~~	~~01h~~	~~O~~	~~N/A~~	~~O~~
~~N1-downlink~~	~~80h~~	~~05h~~	~~O~~	~~N/A~~	~~O~~
~~N1-uplink~~	~~80h~~	~~06h~~	~~O~~	~~N/A~~	~~O~~
~~Counter N2~~	~~80h~~	~~0Ah~~	~~O~~	~~N/A~~	~~O~~
~~Timer T1~~	~~80h~~	~~09h~~	~~O~~	~~N/A~~	~~O~~
~~T-ack~~	~~80h~~	~~08h~~	~~N/A~~	~~0~~	~~N/A~~
~~Private parameters (V)~~					
~~Parameter set ID~~	~~F0h~~	~~00h~~	~~O~~	~~O~~	~~O~~
~~SQP~~	~~F0h~~	~~02h~~	~~O~~	~~O~~	~~O~~
~~LCR cause~~	~~F0h~~	~~06h~~	~~N/A~~	~~N/A~~	~~N/A~~
~~Modulation support~~	~~F0h~~	~~81h~~	~~N/A~~	~~N/A~~	~~N/A~~
~~Private parameters (W)~~					
~~Parameter set ID~~	~~F0h~~	~~00h~~	~~O~~	~~O~~	~~O~~
~~Algorithm version number~~	~~F0h~~	~~01h~~	~~O~~	~~N/A~~	~~O~~
~~Network initialization~~	~~F0h~~	~~02h~~	~~O~~	~~O~~	~~O~~
~~Connection check~~	~~F0h~~	~~03h~~	~~O~~	~~O~~	~~O~~
~~Version~~	~~F0h~~	~~04h~~	~~N/A~~	~~N/A~~	~~O~~
~~Authentication~~	~~F0h~~	~~05h~~	~~O~~	~~O~~	~~O~~
~~Subnetwork User Data~~	~~F0h~~	~~06h~~	~~O~~	~~O~~	~~O~~
~~NM1~~	~~F0h~~	~~42h~~	~~O~~	~~N/A~~	~~O~~
~~RR~~	~~F0h~~	~~43h~~	~~O~~	~~N/A~~	~~O~~
~~WR~~	~~F0h~~	~~44h~~	~~O~~	~~N/A~~	~~O~~
~~RE~~	~~F0h~~	~~46h~~	~~O~~	~~N/A~~	~~O~~
~~RL~~	~~F0h~~	~~47h~~	~~O~~	~~N/A~~	~~O~~
~~Timer T3~~	~~F0h~~	~~48h~~	~~O~~	~~N/A~~	~~O~~
~~NL1~~	~~F0h~~	~~49h~~	~~O~~	~~N/A~~	~~O~~
~~Timer TL3~~	~~F0h~~	~~4Ah~~	~~O~~	~~N/A~~	~~O~~
~~Timer TL4~~	~~F0h~~	~~4Bh~~	~~O~~	~~N/A~~	~~O~~
~~WE~~	~~F0h~~	~~4Ch~~	~~O~~	~~N/A~~	~~O~~
~~Operative_GNI$_p$~~	~~F0h~~	~~4Fh~~	~~O~~	~~O~~	~~O~~
~~Aircraft_TMbB~~	~~F0h~~	~~50h~~	~~O~~	~~O~~	~~O~~
~~MbB_Operations_Permitted~~	~~F0h~~	~~51h~~	~~O~~	~~O~~	~~O~~
~~Expedited recovery~~	~~F0h~~	~~80h~~	~~N/A~~	~~N/A~~	~~N/A~~
~~t~~	~~F0h~~	~~81h~~	~~O~~	~~N/A~~	~~O~~
~~f~~	~~F0h~~	~~82h~~	~~O~~	~~N/A~~	~~O~~
~~Former_GNI$_p$~~	~~F0h~~	~~83h~~	~~O~~	~~O~~	~~O~~
~~Counter NL2~~	~~F0h~~	~~C1h~~	~~O~~	~~N/A~~	~~O~~

~~Table 3-65b: XID Parameters~~

			~~Addressed link parameter modification~~		~~Broadcast link parameter modification~~
	~~Source~~		~~Current ground station~~	~~Aircraft~~	~~Current ground station~~
	~~Destination~~		~~Aircraft~~	~~Current ground Station~~	~~Aircraft~~
~~XID parameters~~	**~~GI~~**	**~~PI~~**	**~~CTRL_CMD_LPM~~**	**~~CTRL_RSP_LPM~~**	**~~CTRL_CMD_LPM (GSIF)~~**
~~Public parameters (8885:1993: Mode 3)~~					
~~Parameter set ID~~	~~80h~~	~~01h~~	~~O~~	~~N/A~~	~~O~~
~~N1-downlink~~	~~80h~~	~~05h~~	~~O~~	~~N/A~~	~~O~~
~~N1-uplink~~	~~80h~~	~~06h~~	~~O~~	~~N/A~~	~~O~~
~~Counter N2~~	~~80h~~	~~0Ah~~	~~O~~	~~N/A~~	~~O~~
~~Timer T1~~	~~80h~~	~~09h~~	~~O~~	~~N/A~~	~~O~~
~~Private parameters (V)~~					
~~Parameter set ID~~	~~F0h~~	~~00h~~	~~O~~	~~O~~	~~O~~
~~SQP~~	~~F0h~~	~~02h~~	~~O~~	~~O~~	~~O~~
~~LCR cause~~	~~F0h~~	~~06h~~	~~N/A~~	~~N/A~~	~~N/A~~
~~Modulation support~~	~~F0h~~	~~81h~~	~~N/A~~	~~N/A~~	~~N/A~~
~~Private parameters (W)~~					
~~Parameter set ID~~	~~F0h~~	~~00h~~	~~O~~	~~O~~	~~O~~
~~Algorithm version number~~	~~F0h~~	~~01h~~	~~O~~	~~N/A~~	~~O~~
~~Network initialization~~	~~F0h~~	~~02h~~	~~O~~	~~O~~	~~O~~
~~Connection check~~	~~F0h~~	~~03h~~	~~O~~	~~O~~	~~O~~
~~Version~~	~~F0h~~	~~04h~~	~~N/A~~	~~N/A~~	~~O~~
~~Authentication~~	~~F0h~~	~~05h~~	~~O~~	~~O~~	~~O~~
~~NM1~~	~~F0h~~	~~42h~~	~~O~~	~~N/A~~	~~O~~
~~RR~~	~~F0h~~	~~43h~~	~~O~~	~~N/A~~	~~O~~
~~WR~~	~~F0h~~	~~44h~~	~~O~~	~~N/A~~	~~O~~
~~RE~~	~~F0h~~	~~46h~~	~~O~~	~~N/A~~	~~O~~
~~RL~~	~~F0h~~	~~47h~~	~~O~~	~~N/A~~	~~O~~
~~Timer T3~~	~~F0h~~	~~48h~~	~~O~~	~~N/A~~	~~O~~
~~NL1~~	~~F0h~~	~~49h~~	~~O~~	~~N/A~~	~~O~~
~~Timer TL3~~	~~F0h~~	~~4Ah~~	~~O~~	~~N/A~~	~~O~~
~~Timer TL4~~	~~F0h~~	~~4Bh~~	~~O~~	~~N/A~~	~~O~~
~~WE~~	~~F0h~~	~~4Ch~~	~~O~~	~~N/A~~	~~O~~
~~Operative_GNI$_p$~~	~~F0h~~	~~4Fh~~	~~O~~	~~O~~	~~O~~
~~Aircraft_TMbB~~	~~F0h~~	~~50h~~	~~O~~	~~O~~	~~O~~
~~MbB_Operations_Permitted~~	~~F0h~~	~~51h~~	~~O~~	~~O~~	~~O~~
~~CT1~~	~~F0h~~	~~52h~~	~~O~~	~~O~~	~~O~~
~~Timer CT2~~	~~F0h~~	~~53h~~	~~O~~	~~O~~	~~O~~
~~Timer CT3~~	~~F0h~~	~~54h~~	~~O~~	~~O~~	~~O~~
~~GDTE~~	~~F0h~~	~~55h~~	~~O~~	~~N/A~~	~~O~~
~~VER~~	~~F0h~~	~~56h~~	~~N/A~~	~~N/A~~	~~O~~
~~M-BIT~~	~~F0h~~	~~57h~~	~~O~~	~~O~~	~~O~~
~~Expedited recovery~~	~~F0h~~	~~80h~~	~~N/A~~	~~N/A~~	~~N/A~~
~~t~~	~~F0h~~	~~81h~~	~~O~~	~~N/A~~	~~O~~
~~f~~	~~F0h~~	~~82h~~	~~O~~	~~N/A~~	~~O~~
~~Former_GNI$_p$~~	~~F0h~~	~~83h~~	~~O~~	~~O~~	~~O~~
~~ADSA~~	~~F0h~~	~~84h~~	~~N/A~~	~~O~~	~~N/A~~
~~Counter NL2~~	~~F0h~~	~~C1h~~	~~O~~	~~N/A~~	~~O~~

~~Key for Table 3-65b above:~~

~~Abbreviations used: GI = ISO 8885 Group Identifier O = Optional M = Mandatory~~
~~PI = ISO 8885 Parameter Identifier N/A = Not applicable h = hexadecimal~~

~~*aircraft that are still in the ground station coverage area when the recovery procedure is invoked.*~~

3.3.2.3.2.5.1 Polling System Configurations

All aircraft shall be polled and respond with a Net Entry Request message per Section G.2.9 to reconstruct associations between ICAO address and local ID. Polling will start at aircraft ID 60 and decrement by one each MAC cycle.

3.3.2.3.2.5.2 Data-Capable System Configurations

If the radio is operating in a system configuration supporting data service, upon receiving the uplink Reservation Response field of the Recovery message indicating that it is granted a slot to transmit, the aircraft shall downlink a CTRL_CMD frame containing an Expedited Recovery XID, per Section 3.3.2.3.3.3.4.2.1, and a Network Initialization XID, per Section 3.3.2.3.3.3.4.1.3 and use an ICAO Address of 0xFFFFFF in place of the Aircraft Station Address of the DLS header, per Section 3.3.2.2.2.2.1, so that the ground station may easily extract the FCS. The Expedited Recovery XID indicates the actual aircraft addressing information as well as information needed to recover the data scheduler. The Network Initialization XID indicates the desired subnetwork connection. The aircraft shall only transmit those network information and network subparameters needed to initialize the network. The CTRL_CMD frame downlinked shall be limited to a single burst transmission so that the ground system can deterministically schedule access during recovery. Additional parameters and network connections should be negotiated after the recovery process is complete.
~~If the radio is operating in a system configuration supporting data service, upon receiving the uplink Reservation Response field of the Recovery message indicating that it is granted a slot to transmit, the aircraft shall downlink a CTRL_RSP frame containing an Expedited Recovery XID, per Section 3.3.2.3.3.3.4.2.1, and a Network Initialization XID, per Section 3.3.2.3.3.3.4.1.3. The Expedited Recovery XID indicates the aircraft addressing information as well as information needed to recover the data scheduler. The Network Initialization XID indicates the desired subnetwork connection. The aircraft shall only transmit those network information and network subparameters needed to initialize the network. The CTRL_RSP frame downlinked shall be limited to a single burst transmission, so that the ground system can deterministically schedule access during recovery. Additional parameters and network connections should be negotiated after the recovery process is complete.~~

Note: *For system configurations 3V1D and 2V1D, all local IDs can be polled faster than all aircraft can access the data subchannel. For 2V2D and 3T, this will also help expedite the procedure, as well as simplify the implementation. As such, it may be desired to allow the* *ground station to skip sending an uplink Recovery message to a local ID that is known to not be assigned due to lack of response to the poll. It may also be desirable to start at the high end of the local identifier range (i.e., aircraft ID 60) and count down to prevent overlap with the data reservations for recovery information so as to maximize its ability to discover open local identifiers before a data slot is wasted. Once the polling reaches the point where the local ID has already been queried via the data reservation, the polling can cease.*

3.3.2.3.2.5.3 Missed Poll

If an aircraft does not receive a poll or reservation grant during the recovery process of its net, it shall assume its connection is no longer valid and wait until normal data flow is resumed before attempting the Net Entry process.

Note: Normal data flow is considered resumed when the Normal message is uplinked instead of the Recovery message.

3.3.2.3.2.5.4 Retransmission

During the recovery procedure, all retransmission counters shall be suspended.

3.3.2.3.2.5.5 Verification

At the completion of the recovery procedure for data-capable system configurations, the ground station shall broadcast a Connection Check XID within a CTRL_CMD_LPM message containing the correlations of local identifier with ICAO aircraft station address for all known aircraft in the user group. Aircraft should verify their entry for correctness. If their aircraft station address is not contained within the message, the aircraft should attempt Link Establishment per Section 3.3.2.3.2.1.

3.3.2.3.2.6 Link Release

3.3.2.3.2.6.1 Explicit Link Release

The aircraft LME shall acknowledge receipt of Next Net information only after receiving the same Next Net message in two consecutive cycles. The procedures for Next Net message transmission, Next Net Acknowledgement, and Next Net retransmission shall be per Section 3.3.2.1.4.3.3.

When the aircraft LME determines that a net handoff is required, the LME shall generate a Leaving Net message and command the MAC sublayer to transmit the Leaving Net message to the ground station and TL3 timer shall be started. When TL3 expires, the link shall be changed to disconnect status, and a leave event message, as required by the supported network stack, shall be formed and delivered to the aircraft router.

> Note: *The aircraft LME could take action to execute a net handoff as a result of three possible prior activities: 1) pilot manually selects new channel and takes actions to execute transfer; 2) a Next Net Command message is uplinked and the pilot takes action to execute the transfer; and 3) the aircraft LME autonomously executes a net handoff (system configuration 3T only).*

After the Leaving Net message is received, the ground shall start TL3 timer, change link status to pending, stop polling the aircraft, and make the Local User ID assigned to the aircraft available for reassignment. When the TL3 expires, the link shall be changed to disconnect status, and a leave event message, as required by the supported network stack, shall be formed and delivered to the ground router(s).

3.3.2.3.2.6.2 Implicit Link Release

When the aircraft LME determines that the poll request is not received from the ground over TL4 MAC cycles (Table 3-66a), the aircraft LME shall start the TL3 timer and execute the net entry procedure described in Section 3.3.2.3.2.1.2.

When the ground LME determines that an aircraft does not respond to the poll requests exceeding the NL2 times (Table 3-66a), the ground LME shall change the link status to disconnect state, and inform the SN-SME and the DLS. A leave event message, as required by the supported network stack, shall be formed and delivered to the associated ground router(s).

3.3.2.3.2.7 Handoff

3.3.2.3.2.7.1 Air-initiated Link Handoff

The aircraft LME shall initiate a link handoff upon being commanded from a manual retuning of the radio, or via the 3T system configuration autotuning capability.

3.3.2.3.2.7.2 Ground-initiated Link Handoff

The ground station LME shall initiate a link handoff upon being commanded to send a Next_Net message to an aircraft.

3.3.2.3.2.7.3 Same GNI

When an aircraft transfers to a new net which is served by the same GNI, the data link between the GNI and the aircraft shall be redirected from the old ground station to the new ground station. To accomplish this, first, the aircraft shall execute the explicit link release procedure described in Section 3.3.2.3.2.6.1 while in the old net. Then, the link establishment procedure described in Section 3.3.2.3.2.1 shall be used to reinstate the link status when the aircraft enters into the new net. The subnetwork virtual connection, if applicable, shall remain undisturbed, while the link layer switches nets.

3.3.2.3.2.7.4 Different GNI

When an aircraft transfers to a new net which is served by a different GNI, the data link between the old GNI and the aircraft shall be disconnected, as described in Section 3.3.2.3.2.6.1 or Section 3.3.2.3.2.6.2. A new data link shall be established following the link establishment procedure, described in Section 3.3.2.3.2.1.

3.3.2.3.2.8 Authentication

3.3.2.3.2.8.1 Signature Verification

If an authentication parameter is included in a CTRL frame, the receiving LME shall process the signature as it is able. The signature shall be hashed over the user data of the CTRL frame with the signature subfield set to all zeros.

3.3.2.3.2.8.2 Unknown Authentication Type

If the receiving LME cannot process the authentication type indicated, the CTRL_RSP frame shall attempt to use another type than that requested, or shall indicate no authentication supported (Authentication Type = 0).

3.3.2.3.2.8.3 Authentication Type Mismatch

If the CTRL_RSP frame contains a different authentication type than that included in the CTRL_CMD frame, the LME shall recognize that the peer LME does not support the type included in the CTRL_CMD frame.

> *Note: It is the responsibility of the end user to determine whether it will reject any mismatch or to alter the method of authentication to be used.*

3.3.2.3.2.8.4 Invalid Signature

If a received authentication parameter contains an invalid signature, the entire CTRL frame shall be discarded and a CTRL_RSP_LCR frame should be sent indicating invalid signature.

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3.3.2.3.3 Link Management Frames

The LME shall process two frame types: M burst frame, and CTRL frame. The M burst frame shall provide link establishment, link release, and link monitoring functions. The CTRL frame shall be used to negotiate the link characteristics when default parameters are not used.

3.3.2.3.3.1 M Burst Message Format

Net Entry Request, Net Entry Response, Next Net Command, Next Net Acknowledge, Leaving Net, and Recovery are the M burst messages which shall be used to establish and release the air/ground link. These message formats are defined in Appendix G.

> Note: *As the M burst message uses a separate logical channel from that employed for user data, the DLS sublayer is bypassed for these messages.*

3.3.2.3.3.2 LME Service System Parameters

The system parameters used in the LME sublayer shall be as specified in Table 3-66a.

Table 3-66a: LME System Parameters

Symbol	Parameter Name	Minimum	Maximum	VDL Mode 3 Default	Increment
WE	Net Entry Request Delay (MAC cycle)	1	256	See Table 3-66b	1
NL1 (air)	Maximum net entry request retry	1	128	20	1
NL2 (gnd)	Polling reply counter	1	255	3	1
TL3	Disconnect delay timer (seconds)	5	30	10	1
TL4 (air)	Polling interval (MAC cycles)	1	600	See Table 3-66b	1

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Table 3-66b: WE and TL4 Parameter Default Values

		System Configuration									
Symbol	Parameter Name	4V	3V1D	2V2D	3T	3V	2V1D	3S	2S1X	1V3D	1V2D
WE	Net Entry Request Delay (MAC cycles)	1	2	2	2	1	2	1	1	4	4
TL4 (air)	Polling Interval (MAC cycles)	480	120	120	120	480	120	240	240	480	480

Note: This table takes into account the possibility that the first six system configurations might be used in sectors with site diversity.

~~Table 3-66a: LME System Parameters~~

~~Symbol~~	~~Parameter Name~~	~~Minimum~~	~~Maximum~~	~~VDL Mode 3 Default~~	~~Increment~~
~~WE~~	~~Net Entry Request Delay (MAC cycle)~~	~~1~~	~~256~~	~~See Table 3-66b~~	~~1~~
~~NL1 (air)~~	~~Maximum net entry request retry~~	~~1~~	~~128~~	~~20~~	~~1~~
~~NL2 (gnd)~~	~~Polling reply counter~~	~~1~~	~~255~~	~~3~~	~~1~~
~~TL3~~	~~Disconnect delay timer~~	~~5 s~~	~~30 s~~	~~10 s~~	~~1 s~~
~~TL4 (air)~~	~~Polling interval (MAC cycles)~~	~~1~~	~~300~~	~~120~~	~~1~~

~~Table 3-66b: WE Parameter Default Values~~

		~~System Configuration~~							
~~Symbol~~	~~Parameter Name~~	~~4V~~	~~3V1D~~	~~2V2D~~	~~3T~~	~~3V~~	~~2V1D~~	~~3S~~	~~2S1X~~

~~WE~~	~~Net Entry Request Delay (MAC cycle)~~	~~1~~	~~2~~	~~2~~	~~2~~	~~1~~	~~2~~	~~1~~	~~1~~

3.3.2.3.3.2.1 Parameter NL1 (Maximum Net Entry Request Retry)

The Net Entry Request message shall be retransmitted no more than NL1 times. When the number of Net Entry Request retransmissions exceeds NL1 before a Net Entry Response message is received, subnetwork layer system management entity (i.e., SN-SME) shall be informed.

3.3.2.3.3.2.2 Counter NL2 (Polling Reply Counter)

Counter NL2 shall represent the maximum number of consecutive polls issued by the ground station to a single aircraft station without receiving a response. When the number of polls exceeds NL2, the Implicit Link procedures identified in Section 3.3.2.3.2.6.2 shall be performed.

3.3.2.3.3.2.3 Timer TL3 (Disconnect Delay Timer)

Timer TL3 defines the time interval that the LME shall wait before the link is changed to disconnect state, and a leave event message, as required by the supported network stack, is sent to the local router.

> *Note: This timer is used by the LME to support link redirection across multiple ground stations.*

3.3.2.3.3.2.4 Timer TL4 (Polling Interval)

Timer TL4 shall represent the maximum number of elapsed MAC cycles between receipt of two consecutive polls. Upon expiration of this timer, the LME shall notify the DLS, SNDCF, and the Voice Unit and attempt to re-establish the link by sending a Net Entry message to the ground station.

~~Timer TL4 shall represent the maximum number of elapsed MAC cycles between receipt of two consecutive polls. Timer TL4 shall be started upon receipt of a poll. Upon expiration of this timer, the upper layers shall be notified.~~

3.3.2.3.3.2.5 Parameter WE (Net Entry Retransmission Delay)

The parameter WE specifies the number of MAC cycles that an aircraft radio shall wait before attempting a Net Entry Request message retransmission.

3.3.2.3.3.3 Exchange Identity (XID) Parameter Format

The user data field of CTRL_CMD and CTRL_RSP frames shall be encoded as defined in ISO 8885 and shall only include the parameters described in Sections 3.3.2.3.3.3.1 through 3.3.2.3.3.5. The CTRL frame containing the XID parameters shall be delivered using the V/D (data) burst. The following order is implied within the parameters:

a. Bit order in each parameter value shall be indicated by subscript numbers. Bit 1 shall indicate the least significant bit.
b. Bits shall be transmitted octet by octet, starting with the parameter ID, and within each octet, the rightmost bit (as shown in the tables) shall be transmitted first.

> *Note: XID parameters are extracted from the DLS sublayer CTRL frames and sent to the LME.*

3.3.2.3.3.3.1 Public Parameters

3.3.2.3.3.3.1.1 General Public Parameters

The general public parameters' XID information field shall be encoded as defined in ISO 8885, with the addition of private parameter data link layer subfields as defined in ISO 8885. The format identifier, hexadecimal 82, shall be used (per Section 3.2.2.5.2.2) to identify the public parameter list identified in ISO 8885. The VDL Mode 3 shall use the public parameter group ID of hexadecimal 80 to indicate negotiation of the common parameters. The public parameter set ID shall be included in CTRL frames if other public parameters are included; the public parameter set ID shall not be included in the CTRL frame if other public parameters are not included. Only the public parameters Unique Identifier (also known as Parameter Set Identifier), Maximum information field length - transmit and receive (N1), Acknowledgment timer (T1), and Retransmission attempts (N2) shall apply to the VDL Mode 3 system.

Note: A Control Frame example is contained in the Manual on the Implementation of the Very High Frequency (VHF) Digital Link Mode 3 (VDL Mode 3) of ICAO.

~~The general public parameters' XID information field shall be encoded as defined in ISO 8885, with the addition of private parameter data link layer subfields as defined in ISO 8885. The format identifier, hexadecimal 82, shall be used (per Section 3.2.2.5.2.2) to identify the public parameter list identified in ISO 8885. The VDL shall use the public parameter group ID of hexadecimal 80 to indicate negotiation of the common parameters. The public parameter set ID shall be included in CTRL frames if other public parameters are included; the public parameter set ID shall not be included in the CTRL frame if other public parameters are not included. Only the public parameters Unique Identifier (also known as Parameter Set Identifier), Maximum information field length - transmit and receive (N1), Acknowledgment timer (T1), and Retransmission attempts (N2) shall apply to the VDL Mode 3 system.~~

3.3.2.3.3.3.1.2 VDL Mode 3 Public Parameters

3.3.2.3.3.3.1.2.1 VDL Mode 3 Public Parameter Set Identifier

The VDL Mode 3 parameter set shall be identified by the ISO IA5 character string "8885:1993:Mode3" encoded per Table 3-67. This parameter shall be included whenever any of the VDL Mode 3 public parameters are sent. It shall be the first VDL Mode 3 public parameter sent per ISO 8885.

Table 3-67: VDL Mode 3 Public Parameter Set Identifier

Parameter ID	0	0	0	0		0	0	0	1	VDL Mode 3 public parameter set
Parameter length	0	0	0	0		1	1	1	1	
Parameter value	0	0	1	1		1	0	0	0	character ‘8’
	0	0	1	1		1	0	0	0	character ‘8’
	0	0	1	1		1	0	0	0	character ‘8’
	0	0	1	1		0	1	0	1	character ‘5’
	0	0	1	1		1	0	1	0	character ‘:’
	0	0	1	1		0	0	0	1	character ‘1’
	0	0	1	1		1	0	0	1	character ‘9’
	0	0	1	1		1	0	0	1	character ‘9’
	0	0	1	1		0	0	1	1	character ‘3’
	0	0	1	1		1	0	1	0	character ‘:’
	0	1	0	0		1	1	0	1	character ‘M’
	0	1	1	0		1	1	1	1	character ‘o’
	0	1	1	0		0	1	0	0	character ‘d’
	0	1	1	0		0	1	0	1	character ‘e’
	0	0	1	1		0	0	1	1	character ‘3’

3.3.2.3.3.3.1.2.2 Timer T1 (Delay Before Retransmission) Parameter

The value of the aircraft Timer T1 (counted in MAC cycles and used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-68.

Table 3-68: Timer T1 Parameter

Parameter ID	0 0 0 0 1 0 0 1	Timer T1 (aircraft)
Parameter length	0 0 0 0 0 0 0 1	
Parameter value	v_8 v_7 v_6 v_5 v_4 v_3 v_2 v_1	value

Note: The ground T1 timer is fixed for performance reasons and to allow for the assumption of reservation of the appropriate random access M bursts for acknowledgement of data reception.

3.3.2.3.3.3.1.2.3 Timer T_ack (Maximum Delay Allowable for Acknowledgement) Parameter

The value of Timer T_ack in MAC cycles (used by ground station) shall be encoded as an unsigned 8-bit integer per Table 3-69.

~~The value of Timer T_ack in MAC cycles (used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-69.~~

Table 3-69: Timer T_ack Parameter

Parameter ID	0 0 0 0 1 0 1 1	Timer T_ack (ground station)
Parameter length	0 0 0 0 0 0 0 1	
Parameter value	v_8 v_7 v_6 v_5 v_4 v_3 v_2 v_1	value

~~Parameter ID~~	~~0 0 0 0 1 0 1 1~~	~~Timer T_ack~~
~~Parameter length~~	~~0 0 0 0 0 0 0 1~~	
~~Parameter value~~	~~v_8 v_7 v_6 v_5 v_4 v_3 v_2 v_1~~	~~value~~

3.3.2.3.3.3.2 Private Parameters

The VDL private parameter identifier shall allow simple identification of the purpose of the parameters defined in Table 3-10.

3.3.2.3.3.3.3 General Private Parameters

Use of any of the parameters defined for VDL Mode 2 use requires the inclusion of the Parameter Set Identification parameter with a value of V as defined in Section 3.2.2.5.2.4.1.

3.3.2.3.3.3.3.1 General Purpose Information Private Parameters

VDL Mode 3 shall use a subset of the general purpose information private parameters defined in Section 3.2.2.5.2.4, which includes the parameter set identification parameter (Section 3.2.2.5.2.4.1), signal quality parameter (Section 3.2.2.5.2.4.3), and LCR cause parameter (Section 3.2.2.5.2.4.7).

3.3.2.3.3.3.3.2 Aircraft-Initiated Information Private Parameters

VDL Mode 3 shall use the modulation support parameter defined in Section 3.2.2.5.2.5.1.

3.3.2.3.3.3.4 VDL Mode 3 Private Parameters

3.3.2.3.3.3.4.1 General Purpose Information Private Parameters

Both aircraft and ground LMEs shall use general purpose information private parameters to transfer VDL Mode 3 basic information to each other.

3.3.2.3.3.3.4.1.1 Private Parameter Set Identifier

This parameter shall be required whenever any of the VDL Mode 3 private parameters are to be sent. It shall be the first parameter sent per Table 3-70.

Table 3-70: Parameter Set Identification

Parameter ID	0	0	0	0	0	0	0	0	Parameter set identification
Parameter length	0	0	0	0	0	0	0	1	
Parameter value	0	1	0	1	0	1	1	1	Character W

3.3.2.3.3.3.4.1.2 Algorithm Version Number Parameter

This parameter shall be used by the aircraft and ground station to indicate vocoder algorithm versions supported. This parameter shall be encoded as a variable length bit-field per Table 3-71a with each bit being set to indicate the support for a specific algorithm version per Table 3-71b.

Table 3-71a: Algorithm Version Number Parameter

Parameter ID	0	0	0	0	0	0	0	1	Algorithm Ver. No.
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	
Parameter value	b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1	value

Table 3-71b: Vocoder Algorithm Version Encoding

Bit #	Algorithm Version
1	AMBE-ATC-10 or equivalent vocoder
2	Not currently specified
3	Not currently specified
4	Not currently specified
5	Not currently specified
6	Not currently specified
7	Not currently specified
8	Not currently specified

3.3.2.3.3.3.4.1.3 Network Initialization Parameter.

The network initialization parameter defines the network support which the avionics VDL Mode 3 installation can perform. It is used to pass any necessary information to initialize the subnetwork protocol or any compression. Table 3-72a defines the format of this parameter set. The length field shall contain the number of networks present. For each network, a length field shall indicate the number of subparameters. If no subparameters are needed for a network, then that network's length field shall indicate zero.

Notes: 1. As many networks as applicable can appear, as defined in Table 3-72b.

2. It is assumed that the ground system will support all options and the aircraft system will support at least one. ~~**3.3.2.3.3.3.4.1.3 Network Initialization Parameter**~~

~~The network initialization parameter defines the network support which the avionics VDL Mode 3 installation can perform. It is used to pass any necessary information to initialize the subnetwork protocol or any compression. Table 3-72a defines the format of this parameter set. The length field shall contain the number of networks present. For each network, a length field shall indicate the number of subparameters. If no subparameters are needed for a network, then that network's length field shall indicate zero.~~

~~*Notes:*~~

1. ~~*As many networks as applicable can appear, as defined in Table 3-72b.*~~

2. ~~*It is assumed that the ground system will support all options and the aircraft system will support at least one.*~~

Table 3-72a: Network Initialization

Parameter ID	0 0 0 0	0 0 1 0	Network Initialization
Parameter Length	$n_8\ n_7\ n_6\ n_5$	$n_4\ n_3\ n_2\ n_1$	Number of networks
Network Type	$T_8\ T_7\ T_6\ T_5$	$T_4\ T_3\ T_2\ T_1$	May contain multiple networks
Network Length	$S_8\ S_7\ S_6\ S_5$	$S_4\ S_3\ S_2\ S_1$	Number of subparameters
Subparameter ID	$I_8\ I_7\ I_6\ I_5$	$I_4\ I_3\ I_2\ I_1$	May contain multiple subparameters for each network
Subparameter Length	$L_8\ L_7\ L_6\ L_5$	$L_4\ L_3\ L_2\ L_1$	Length of Value in octets
Subparameter Value	$v_8\ v_7\ v_6\ v_5$	$v_4\ v_3\ v_2\ v_1$	value

Table 3-72b Network Type Values

Network Type	**Protocol**
0000 0000	ATN/ISO 8208/VDL Mode 3 PLP Compression
0000 0001	ATN/ISO 8473/ISO 9542/VDL Mode 3 CLNP Compression
0000 0010	ATN/ISO 8208 (No Subnetwork Compression)
0000 0011	ATN/ISO 8473/ISO 9542 (No Subnetwork Compression)
0000 0100	Raw/VDL
0000 0101	ATN Frame Mode
0000 0110 to 1111 1111	Reserved

A Network Type value of zero indicates that the VDL Mode 3 system is carrying ISO8208 packets which shall be transferred to an ATN ISO8208 DCE at the remote end. The ISO8208 packets

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shall be compressed using the VDL Mode 3 PLP Compression as defined in Section 3.3.3.2.1. A Network Type value of one indicates that the VDL Mode 3 system is carrying ATN CLNP packets which shall be transferred to an ATN-conformant CLNP service at the remote end. The CLNP packets shall be compressed using the VDL Mode 3 compression as defined in Section 3.3.3.2.2. A Network Type value of two indicates that: (1) The VDL Mode 3 system is carrying ISO8208 packets which shall be transferred to an ATN ISO8208 DCE at the remote end; and (2) No compression is performed. Similarly, a Network Type value of three indicates that the VDL Mode 3 system is carrying ATN CLNP packets which shall be transferred to an ATN-conformant CLNP service at the remote end with no compression. A Network Type Value of four indicates that no (sub) network protocol shall be used. Data shall be sent to the remote end unmodified with no (sub) network operands. A Network Type Value of five indicates that the VDL Mode 3 system is carrying ATN frame mode packets which shall be transferred to an ATN Frame Mode SNDCF at the remote end without compression within the subnetwork.

Notes: 3. The ATN designation tells the VDL Mode 3 system to support any ATN-specific requirements. For example, ATN join and leave events will be generated when network types of 0, 1, 2, 3, or 5 are sent from the aircraft to the ground.

4. An indication of No Compression in this parameter only indicates that the VDL Mode 3 subnetwork performs no compression. This does not indicate or prohibit any compression by the network or higher layers.

5. The ground station will support all Network Types.

6. The use of the raw interface requires that the largest packet received with the addition of the payload and DLS frame header be a maximum of 930 bytes as no segmentation of the data is possible.

~~Table 3-72b: Network Type Values~~

~~Network Type~~	**~~Protocol~~**
~~0000 0000~~	~~ATN/ISO 8208/VDL Mode 3 PLP Compression~~
~~0000 0001~~	~~ATN/ISO 8473/ISO 9542/VDL Mode 3 CLNP Compression~~
~~0000 0010~~	~~ATN/ISO 8208 (No Subnetwork Compression)~~
~~0000 0011~~	~~ATN/ISO 8473/ISO 9542 (No Subnetwork Compression)~~
~~0000 0100~~	~~Raw/VDL~~
~~0000 0101 to 1111 1111~~	~~Reserved~~

~~A Network Type value of zero indicates that the VDL Mode 3 system is carrying ISO 8208 packets which shall be transferred to an ATN ISO 8208 DCE at the remote end. The ISO 8208 packets shall be compressed using the VDL Mode 3 PLP Compression as defined in Section 3.3.3.2.1. A Network Type value of one indicates that the VDL Mode 3 system is carrying ATN CLNP packets which shall be transferred to an ATN-conformant CLNP service at the remote end. The CLNP packets shall be compressed using the VDL Mode 3 compression as defined in Section 3.3.3.2.2. A Network Type value of two indicates that: (1) The VDL Mode 3 system is carrying ISO 8208 packets which shall be transferred to an ATN ISO 8208 DCE at the remote end; and (2) No compression is performed. Similarly, a Network Type value of three indicates that the VDL Mode 3 system is carrying ATN CLNP packets which shall be transferred to an ATN-conformant CLNP service at the remote end with no compression. A Network Type Value of 4 indicates that no~~

~~(sub)network protocol shall be used. Data shall be sent to the remote end unmodified with no (sub)network operands.~~

~~*Notes:*~~

3. ~~*The ATN designation tells the VDL Mode 3 system to support any ATN-specific requirements. For example, ATN join and leave events will be generated when network types of 0, 1, 2, or 3 are sent from the aircraft to the ground.*~~

4. ~~*An indication of No Compression in this parameter only indicates that the VDL Mode 3 subnetwork performs no compression. This does not indicate or prohibit any compression by the network or higher layers.*~~

5. ~~*The ground station will support all Network Types.*~~

6. ~~*The use of the raw interface requires that the largest packet received with the addition of the payload and DLS frame header be a maximum of 930 bytes as no segmentation of the data is possible.*~~

3.3.2.3.3.3.4.1.4 Connection Check Parameter

This parameter shall be used to inform peer link entities of the correlation of local identifiers with ICAO aircraft station addresses per Table 3-73a. The length field identifies the number of 4 octet Local ID/ICAO Address correlations included. The value field shall contain one or more Local ID/ICAO address pairs, according to the length field. If an aircraft is requesting to identify the local identifier for a specific ICAO address, the Local ID of 61 should be used. If the ground station has no Local ID correlated with a specified ICAO address, it shall respond with a Local ID of 61 to indicate no correlation.

Table 3-73a: Connection Check Parameter

Parameter ID	0	0	0	0		0	0	1	1	Connection Check
Parameter length	n_8	n_7	n_6	n_5		n_4	n_3	n_2	n_1	
Parameter value	L_8	L_7	L_6	L_5		L_4	L_3	L_2	L_1	Local ID
	a_{24}	a_{23}	a_{22}	a_{21}		a_{20}	a_{19}	a_{18}	a_{17}	ICAO address
	a_{16}	a_{15}	a_{14}	a_{13}		a_{12}	a_{11}	a_{10}	a_9	
	a_8	a_7	a_6	a_5		a_4	a_3	a_2	a_1	

3.3.2.3.3.3.4.1.5 Version Parameter

This parameter shall be used to indicate the protocol version being supported by the transmitting protocol. The parameter shall be encoded per Table 3-73b. The value subfield shall be encoded per Table 3-73c.

Table 3-73b: Version Parameter

Parameter ID	0	0	0	0		0	1	0	0	Version
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	n_8	n_7	n_6	n_5		n_4	n_3	n_2	n_1	

Table 3-73c: Version Values

Version Value	**Protocol Version**
0000 0000	4.0, dated November 2001
0000 0001 to 1111 1111	Reserved

3.3.2.3.3.3.4.1.6 Authentication Parameter

This parameter shall be used optionally to authenticate XID transactions. The parameter shall be encoded per Table 3-73d, with the variable-length value field containing a single octet Type subfield to identify the method of authentication being used per Table 3-73e and the remainder of the value field being used for the signature. If the Authentication Type subfield indicates 'None Supported', the Signature subfield shall not be included.

Table 3-73d: Authentication Parameter

Parameter ID	0	0	0	0		0	1	0	1	Authentication
Parameter length	n_8	n_7	n_6	n_5		n_4	n_3	n_2	n_1	
Parameter value	t_8	t_7	t_6	t_5		t_4	t_3	t_2	t_1	Type
	s_n	s_{n-1}	s_{n-2}	s_{n-3}		s_{n-4}	s_{n-5}	s_{n-6}	s_{n-7}	
	s_8	s_7	s_6	s_5		s_4	s_3	s_2	s_1	Signature

Table 3-73e: Authentication Type

Authentication Type	**Authentication Protocol**
0000 0000	None Supported
0000 0001	User Agreed
0000 0010 to 1111 1111	*Reserved*

3.3.2.3.3.3.4.1.7 Subnetwork User Data Parameter.

The subnetwork user data parameter allows for any subnetwork or network level messages to be combined with the CTRL frame exchange, such as ISH packets. The subnetwork user data parameter format shall be as defined in Table 3-73f. If included as a subparameter in the Network Initialization parameter, the content of the value field shall be forwarded to the subnetwork interface for which this is a subparameter. Otherwise, the content of the value field shall be forwarded to the raw subnetwork interface.

Table 3-73f: Subnetwork User Data Parameter

Parameter ID	0	0	0	0	0	1	1	0	User Data
Parameter length	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	
Parameter value	v_8	v_7	v_6	v_5	v_4	v_3	v_2	v_1	Value

3.3.2.3.3.3.4.1.8 Assigned Altitude Parameter

The Assigned Altitude parameter, used by the ground station, shall be encoded as an unsigned 16-bit integer in units of 1 foot relative to mean sea level per Table 3-73g.

Table 3-73g: Assigned Altitude Parameter

Parameter ID	0	0	0	0	0	1	1	1	Assigned Altitude
Parameter length	0	0	0	0	0	0	1	0	
Parameter value	v16	v15	v14	v13	v12	v11	v10	v9	Value
	v8	v7	v6	v5	v4	v3	v2	v1	

3.3.2.3.3.3.4.2 Air-initiated Information Private Parameters

An aircraft LME shall use aircraft-initiated information private parameters to inform the ground about the aircraft's VDL Mode 3 capabilities or desires. Ground LMEs shall not send these parameters.

3.3.2.3.3.3.4.2.1 Expedited Recovery Parameter

The Expedited Recovery parameter shall be used by the aircraft to communicate its MAC sublayer state to allow the ground MAC sublayer to reload its state information. Table 3-74 defines the format of this parameter. The aircraft address shall be the 24-bit ICAO aircraft station address. The Reservation Status field shall include a 2-bit priority field and a 4-bit Number of Slots field indicating at what priority and how many slots are needed for any outstanding data requests for the aircraft. Upon reception by the ground station, this information shall be forwarded to the MAC sublayer.

Table 3-74: Expedited Recovery Parameter

Parameter ID	1	0	0	0		0	0	0	0	Expedited Recovery
Parameter length	0	0	0	0		0	1	0	1	
Parameter Value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	Local Identifier
	a_{24}	a_{23}	a_{22}	a_{21}		a_{20}	a_{19}	a_{18}	a_{17}	Aircraft Address
	a_{16}	a_{15}	a_{14}	a_{13}		a_{12}	a_{11}	a_{10}	a_9	
	a_8	a_7	a_6	a_5		a_4	a_3	a_2	a_1	
	0	0	p_2	p_1		s_4	s_3	s_2	s_1	Reservation Status

3.3.2.3.3.3.4.2.2 t (Truncation) Parameter

The value of t (in MAC cycles used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-75.

Table 3-75: t Parameter

Parameter ID	1	0	0	0		0	0	0	1	t
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.2.3 f (Free Running) Parameter

The value of f (in MAC cycles used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-76a.

Table 3-76a: f Parameter

Parameter ID	1	0	0	0		0	0	1	0	f
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.2.4 Former_GNIp Parameter

The former_GNIp parameter shall be encoded as an unsigned 8-bit integer per Table 3-76b. The high order 2 bits must be zero, resulting in a range of 0 to 63 values.

Table 3-76b: Former_GNI$_p$ Parameter

Parameter ID	1	0	0	0		0	0	1	1	former_GNI$_p$
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3 Ground-initiated Modification Private Parameters

A ground LME shall use the ground-initiated modification parameters to change the value of various VDL Mode 3 parameters in one or more aircraft. Aircraft LMEs shall not send an XID with these parameters.

3.3.2.3.3.3.4.3.1 NM1 (Maximum Retry) Parameter

The value of NM1 (used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-77.

Table 3-77: NM1 Parameter

Parameter ID	0	1	0	0		0	0	1	0	Parameter NM1
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.2 RR (Reservation Request Randomizer) Parameter

The value of RR (used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-78. This negotiation shall only affect the parameter for the current system configuration.

Table 3-78: RR Parameter

Parameter ID	0	1	0	0		0	0	1	1	RR
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.3 WR (Reservation Request Delay) Parameter

The value of WR (in MAC cycles used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-79. This negotiation shall only affect the parameter for the current system configuration.

Table 3-79: WR Parameter

Parameter ID	0	1	0	0		0	1	0	0	WR
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.4 RE (Net Entry Randomizer) Parameter

The value of RE (used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-80. This negotiation shall only affect the parameter for the current system configuration.

Table 3-80: RE Parameter

Parameter ID	0	1	0	0		0	1	1	0	RE
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.5 RL (Leaving Net Randomizer) Parameter

The value of RL (used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-81. This negotiation shall only affect the parameter for the current system configuration.

Table 3-81: RL Parameter

Parameter ID	0	1	0	0		0	1	1	1	RL
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.6 Timer T3 (Link Initialization Time) Parameter

The value of timer T3 (in MAC cycles used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-82.

Table 3-82: Timer T3 Parameter

Parameter ID	0	1	0	0		1	0	0	0	Timer T3
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.7 NL1 (Maximum Net Entry Request Retry) Parameter

The value of NL1 (used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-83.

Table 3-83: NL1 Parameter

Parameter ID	0	1	0	0		1	0	0	1	Parameter NL1
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.8 Timer TL3 (Disconnect Delay Timer) Parameter

The value of timer TL3 (in seconds used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-84.

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Table 3-84: Timer TL3 Parameter

Parameter ID	0	1	0	0		1	0	1	0	Timer TL3
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.9 Timer TL4 (Polling Interval) Parameter

The value of timer TL4 (in seconds used by aircraft) shall be encoded as an unsigned 16-bit integer per Table 3-85.

Table 3-85: Timer TL4 Parameter

Parameter ID	0	1	0	0		1	0	1	1	Timer TL4
Parameter length	0	0	0	0		0	0	1	0	
Parameter value	v_{16}	v_{15}	v_{14}	v_{13}		v_{12}	v_{11}	v_{10}	v_9	value
	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	

3.3.2.3.3.3.4.3.10 WE (Net Entry Request Delay) Parameter

The value of WE (in MAC cycles used by aircraft) shall be encoded as an unsigned 8-bit integer per Table 3-86. This negotiation shall only affect the parameter for the current system configuration.

Table 3-86: WE Parameter

Parameter ID	0	1	0	0		1	1	0	0	WE
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.11 Operative_ GNIp Parameter

The operative_GNIp parameter shall be encoded as an unsigned 8-bit integer per Table 3-88. The high order 2 bits must be zero, resulting in a range of 0 to 63 values.

Table 3-88: Operative_GNIp Parameter

Parameter ID	0	1	0	0		1	1	1	1	operative_GNIp
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.4.3.12 Aircraft_TMbB Parameter

The Aircraft_TMbB parameter shall be encoded as an unsigned 16-bit integer per Table 3-89. The Aircraft_TMbB parameter is a timer with each increment representing one second.

Table 3-89: Aircraft_TMbB Parameter

Parameter ID	0	1	0	1		0	0	0	1	aircraft_TMbB
Parameter length	0	0	0	0		0	0	1	0	
Parameter value	v_{16}	v_{15}	v_{14}	v_{13}		v_{12}	v_{11}	v_{10}	v_9	value

3.3.2.3.3.3.4.3.13 MbB_Operations_Permitted

The MbB_Operations_Permitted parameter shall be encoded as an unsigned 8-bit integer per Table 3-90. There shall be two permissible values. The encoding of 01(hex) shall correspond to the logical value of TRUE. The encoding of 00 (hex) shall correspond to the logical value of FALSE.

Table 3-90: MbB_Operations_Permitted Parameter

Parameter ID	0	1	0	1		0	0	1	0	MbB_Operations_Permitted

Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

3.3.2.3.3.3.~~5~~ 4 Ground-initiated Information Private Parameters

A VDL Mode 3 ground LME shall use ground-initiated information private parameters to inform one or more aircraft LMEs about that ground system's capabilities. Aircraft LMEs shall not send these parameters.

3.3.2.3.3.3.~~5.1~~4.1 Counter NL2 (Polling Reply) Parameter

The NL2 counter, used by the ground station, shall be encoded as an unsigned 8-bit integer per Table 3-87.

Table 3-87: Counter NL2 Parameter

Parameter ID	1	1	0	0		0	0	0	1	Counter NL2
Parameter length	0	0	0	0		0	0	0	1	
Parameter value	v_8	v_7	v_6	v_5		v_4	v_3	v_2	v_1	value

~~3.3.2.3.3.3.5.2 Operative_ GNIp Parameter~~

~~The operative_GNIp parameter shall be encoded as an unsigned 8-bit integer per Table 3-88. The high order 2 bits must be zero, resulting in a range of 0 to 63 values.~~

~~Table 3-88: Operative_GNIp Parameter~~

~~Parameter ID~~	~~0~~	~~1~~	~~0~~	~~0~~		~~1~~	~~1~~	~~1~~	~~1~~	~~operative_GNIp~~
~~Parameter length~~	~~0~~	~~0~~	~~0~~	~~0~~		~~0~~	~~0~~	~~0~~	~~1~~	
~~Parameter value~~	~~v_8~~	~~v_7~~	~~v_6~~	~~v_5~~		~~v_4~~	~~v_3~~	~~v_2~~	~~v_1~~	~~value~~

~~3.3.2.3.3.3.5.3 Aircraft_TMbB Parameter~~

~~The Aircraft_TMbB parameter shall be encoded as an unsigned 16-bit integer per Table 3-89. The Aircraft_TMbB parameter is a timer with each increment representing one second.~~

~~Table 3-89: Aircraft_TMbB Parameter~~

~~Parameter ID~~	~~0~~	~~1~~	~~0~~	~~1~~		~~0~~	~~0~~	~~0~~	~~1~~	~~aircraft_TMbB~~
~~Parameter length~~	~~0~~	~~0~~	~~0~~	~~0~~		~~0~~	~~0~~	~~1~~	~~0~~	
~~Parameter value~~	~~v_{16}~~	~~v_{15}~~	~~v_{14}~~	~~v_{13}~~		~~v_{12}~~	~~v_{11}~~	~~v_{10}~~	~~v_9~~	~~value~~

~~3.3.2.3.3.3.5.4 MbB_Operations_Permitted~~

~~The MbB_Operations_Permitted parameter shall be encoded as an unsigned 8-bit integer per Table 3-90. There shall be two permissible values. The encoding of 01(hex) shall correspond to the logical value of TRUE. The encoding of 00 (hex) shall correspond to the logical value of FALSE.~~

~~Table 3-90: MbB_Operations_Permitted Parameter~~

~~Parameter ID~~	~~0~~	~~1~~	~~0~~	~~1~~		~~0~~	~~0~~	~~1~~	~~0~~	~~MbB_Operations_Permitted~~
~~Parameter length~~	~~0~~	~~0~~	~~0~~	~~0~~		~~0~~	~~0~~	~~0~~	~~1~~	
~~Parameter value~~	~~v_8~~	~~v_7~~	~~v_6~~	~~v_5~~		~~v_4~~	~~v_3~~	~~v_2~~	~~v_1~~	~~value~~

3.3.3 Subnetwork Layer Protocols and Services (VDL Mode 3)

3.3.3.1 Payload Identification

For each Information frame sent by the VDL Mode 3 system, a payload identification octet shall be defined as in Figure 3-10. This octet shall be the first octet appearing in the user data field of the Information frame. The user data as described by the payload octet shall immediately follow. The Type field shall identify the network protocol of the user data.

1	2	3	4	5	6	7	8
Type-specific Info				Type			

BIT	**PROTOCOL**
0000	ISO 8208
0001	ISO 8473/ISO 9542
0010	Raw
0011	ATN Frame Mode
0100 - 1111	Reserved

Figure 3-10. Payload octet

~~1~~	~~2~~	~~3~~	~~4~~	~~5~~	~~6~~	~~7~~	~~8~~
~~Type-specific Info~~				~~Type~~			

~~**BIT**~~	~~**PROTOCOL**~~
~~0000~~	~~ISO 8208~~
~~0001~~	~~ISO 8473/ISO 9542~~
~~0010~~	~~Raw~~
~~0011 - 1111~~	~~Reserved~~

~~**Figure 3-10: Payload Octet**~~

3.3.3.2 Compression Signaling

For each network packet transferred, an indication that the packet is compressed or not compressed shall exist. The Type Specific Information Field located in the Payload octet shall be reserved for this purpose. A value of all zeros (0000 binary) shall be reserved to indicate that no compression information is present, i.e., the data is not compressed. Additional values for the Type Specific Information Field are possible and are dependent on the compression scheme employed. These values shall be defined with the compression documentation, as necessary.

> *Note: The compression scheme employed for a particular network type is signaled in a DLS Control frame during net entry. The non-zero values of the Type-Specific Information Field of Figure 3-10 have meaning only with respect to the specific compression defined for a network protocol.*

3.3.3.2.1 ISO 8208 Compression

The compression technique to be used for ISO 8208 shall be defined in Appendix J. Appendix J defines the architecture, procedures, and packet formats for packets received from or sent to the local DTE when ISO 8208 compression is signaled. The term "ISO 8208" when used throughout Appendix J refers to the ISO Standard, "Information Technology - Data Communications - X.25 Packet Layer Protocol for Data terminal Equipment, Reference Number ISO/IEC 8208: 1990(E)."

3.3.3.2.2 CLNP Compression

The compression technique to be used for CLNP packets shall be defined in Appendix K. The Type-Specific Information subfield of the Payload octet shall be encoded per Figure K-3. For non-compressed CLNP, the Type-Specific Information subfield shall be binary 0000.

3.3.3.2.3 Raw Payload Type

The type-specific information field shall be set to all zeros whenever a payload of raw is specified.

3.3.3.2.4 ATN Frame M~~a~~ode Payload Type

The type-specific information field shall be set to all zeros whenever a payload of 'ATN Frame Mode' is specified.

3.3.3.3 Make-before-Break (MbB) Operation

Make-before-Break refers to a set of protocols that allow the VDL Mode 3 system to provide uninterrupted availability when an aircraft transitions between regions served by different ATN routers. MbB maintains user availability by providing a path from ground end-systems, to a ground ATN router, to the attached GNI that no longer has radio contact with the aircraft, to the GNI that presently has radio contact, to the aircraft ATN router, and finally to the aircraft end-system. Simultaneously, a path from a different ground ATN router, to its attached GNI that presently has radio contact, and finally to the aircraft ATN router, is maintained for the purposes of network initiation. After network initiation, the latter path can be used by end-system applications.

3.3.3.3.1 General Requirements

MbB capability shall be required for those aircraft that have installed ATN conformant routers that are running the InterDomain Routing Protocol (IDRP, ISO10747).

MbB operations shall be applied on an aircraft by aircraft basis.

3.3.3.3.1.1 GNIp-Group Addressing

For the group of GNIs that are associated with the same ATN router, a primary GNI, represented as GNIp, shall be designated. Each GNIp shall be assigned a non-zero identifier that is unique with respect to the set of GNIps that an aircraft can contact at any one time. The identifier shall be 6 bits in length and is denoted the ground subnetwork address per Section 3.3.2.2.2.4.1. The group of GNIs associated with a GNIp is denoted the GNIp-group.

3.3.3.3.1.2 GNIp-Group Parameter Set

All GNIs within a GNIp-group shall uplink as part of the link establishment negotiation, an MbB parameter set. The MbB parameter set shall consist of the following three parameters.

1) Operative_GNIp: The ground subnetwork address of the GNIp. The Operative_GNIp is the same for all GNIs within the GNIp group.

2) Aircraft_TMbB: A timer value which determines the duration within the aircraft of MbB operations involving the operative_GNIp.

3) MbB_Operations_Permitted: A declaration that the communicating GNIp can support MbB operations with the GNIp identified by the former_GNIp parameter (see Section 3.3.3.3.2.1).

3.3.3.3.2 MbB Avionics Requirements

The aircraft VDL Mode 3 system shall provide sufficient information to the local ATN router so that the router can maintain the correspondence between the NET of the remote ground router and the attached GNIp ground network address.

Note: *The following methods are suggested in order to determine the correspondence.*

- *Join Event messages are generated and sent to the local ATN router, whenever the CTRL_RSP_LE frame is received following the receipt of a Net Entry Response M burst message of type "no previous link." The link address, provided within the Join Event message, is that of the provided operative_GNIp XID parameter. The ATN router will subsequently send an ISH packet with the destination defined as the ground subnetwork address, i.e., the operative_GNIp. This elicits an ISH from the ground ATN router, which is received by the aircraft router. The NET of the ground router contained in the ISH packet can now be associated with the initiating Join Event message and its provided link address.*

- *The VDL Mode 3 avionics supplies the ground subnetwork address of the encapsulating frame for all packets transferred to the local ATN router.*

- *The NET of the remote router includes within the system identifier field sufficient information to deduce the ground subnetwork address.*

3.3.3.3.2.1 Initialization

An aircraft requesting MbB operations shall include the XID parameter "former_GNIp" as part of all initial link negotiation procedures as defined in Section 3.3.2.3.2.1.3. The value of the former_GNIp is that of the latest operative_GNIp parameter, determined during the last link establishment. If the MbB parameter set is missing, incomplete, or contact with the GNI that last performed link establishment has not been possible during the last TL3 (see Section 3.3.2.3.3.2) seconds, the former_GNIp parameter shall be set to zero.

3.3.3.3.2.2 Determining MbB Applicability in the Aircraft

An aircraft shall participate in MbB operations with a GNIp, when during link establishment the following conditions are met.

1. A complete MbB parameter set is received
2. The received MbB_Operations_Permitted parameter has a value of TRUE.

3. The former_GNIp parameter is of non-zero value.

4. The received operative_GNIp parameter is non-zero.

5. The former_GNIp and operative_GNIp are not equal.

If these conditions are not met, the aircraft shall not participate in MbB operations.

3.3.3.3.2.3 Aircraft MbB-Operation

Once the aircraft has determined that it is participating in MbB operations for a particular GNIp-group, the following shall occur.

1. The aircraft shall delay the generation of a Leave Event Message for the former_GNIp until one of the following events takes place:

    a. Aircraft_TMbB seconds pass after the beginning of participation in MbB operations.

    b. A new MbB parameter set is received via an XID transfer that contains an operative_GNIp identifier not matching the stored former_GNIp.

    c. The MbB_Operations_Permitted parameter value is FALSE as a result of the uplink of a new MbB parameter set.

2. Each subnetwork packet received from the local ATN router shall be encapsulated in a frame, as defined in Section 3.3.2.2.2.1. The Ground Subnetwork Address field in the DLS sublayer frame header shall be set to the next hop link address value accompanying the packet received from the ATN router.

3. If CLNP compression is occurring, the aircraft CLNP compression utility shall be provided the ground subnetwork address for each packet. This is done to assure the uniqueness of the index number for each GNIp and to restrict compression restart operation on reception of a restart packet to the indices associated with the originating GNIp.

    Note: *Each packet forwarded to the VDL Mode 3 avionics system by the local ATN router will contain the next hop destination address to use. The next hop destination defines the ground subnetwork address field in each VDL Mode 3 frame, and is known as a result of the router interface procedures described in Section 3.3.3.3.2, Note 1. In this way established and newly required end-system communications will use the path* *corresponding to the former_GNIp. IDRP initialization will occur using the path corresponding to the operative_GNIp. Once IDRP has initialized, both former and operative GNIp paths will be used until the Aircraft_TMbB timer expires and the former_GNIp path is withdrawn.*

3.3.3.3.3 GNIp Requirements

Any GNIp that supports MbB operations shall keep a list of all surrounding GNIps (not including itself) with which it is capable of communicating for the purposes of MbB. This list is denoted the MbB-list.

3.3.3.3.3.1 Determining MbB Applicability on the Ground

The operative_GNIp is that GNIp through which communications is actively occurring, i.e., the aircraft has presently entered the net of a GNI within the GNIp-group. Whenever: (1) an aircraft begins the link establishment protocol, per Sections 3.3.2.3.2.1 and 3.3.3.3, (2) the operative_GNIp has sent a Net Entry Response of type "no previous link," per Section 3.3.2.3.2.1.2, and (3) a CTRL_CMD_LE has been received, the operative_GNIp shall examine the downlinked former_GNIp XID parameter of the CTRL_CMD_LE frame. If the parameter value matches a GNIp identifier on the MbB-list, the operative_GNIp will set the MbB_Operations_Permitted parameter to TRUE. Otherwise this parameter's value is FALSE. The MbB parameter set, as defined in Section 3.3.3.3.1, is then uplinked according to the XID procedures defined in Section 3.3.2.3.2.3.1 . All subsequent XID parameter exchanges occurring with any GNI that is a member of the GNIp-group shall contain the MbB parameter set.

> Note: *After a CTRL_RSP_LE is received with a MbB parameter set, the aircraft will update the value of the former_GNIp with that of the operative_GNIp parameter and use this value in subsequent link establishment parameter exchanges. This means that the GNIp must only use the first value received to determine the necessary GNI with which to switch.*

3.3.3.3.3.2 Compatibility with Aircraft not Requesting MbB Capability

If the former_GNIp parameter is not among the downlinked XID parameters, then the operative_GNIp shall not include the MbB parameter set in any XID exchanges and shall not perform any MbB operations in support of the aircraft.

3.3.3.3.3.3 Operative_GNIp Requirements

Upon acknowledgement by the aircraft of successful receipt of the MbB parameter set, the operative_GNIp performs the following actions.

1. The operative_GNIp shall supercede any existing switching information involving the aircraft with the more recent information,

2. The operative_GNIp shall (re)initialize the operative_TMbB timer. This parameter defines the maximum length of time during which the operative_GNIp performs switching functions in support of MbB.

3. The operative_GNIp shall send a message to the former_GNIp identified in the link establishment XID exchange. This message informs the former_GNIp of the operative_GNIP for the aircraft.
4. The operative_GNIp shall provide complete Acknowledged Connectionless Data Link (A-CLDL) functions (see Section 3.3.2.2) for all frames transmitted or received from the aircraft, as long as the ground subnetwork address is in the MbB-list.

5. The operative_GNIp shall deliver each frame successfully received from the A-CLDL function to the GNIp identified in the ground subnetwork address field of the frame header, so long as it is in the MbB-list.

6. The operative_GNIp shall compress packets received from the locally attached ATN router and encapsulate the result in a DLS sublayer frame. The ground subnetwork address value associated with the operative_GNIp is used when constructing the frame header associated with each packet.

7. The operative_GNIp shall decompress packets received from the aircraft (i.e., packets contained in frames with a ground subnetwork address value of the operative_GNIp), as required and forward to the local ATN router.

8. The operative_GNIp shall forward frames received from the former_GNIp to the aircraft identified in the frame header, providing all necessary DLS support.

9. The operative_GNIp shall set the MbB_Operations_Permitted parameter to FALSE, if at any time the following occurs.

   a. The local ATN router notifies the operative_GNIp that IDRP has completed initialization.

   b. The ground subnetwork address field value for a frame received from an aircraft is one with which the operative_GNIp does not have MbB capability.

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c. After sending a message of type "previous link preserved," a CTRL_CMD_LE message is received with a former_GNIp parameter value that is not equal to the ground subnetwork address of the operative_GNIp thereby implying a change in the GNIp when there should not be.

d. Communications for the purposes of MbB operations ceases with the former_GNIp for any reason. In which case the new MbB_Operations_Permitted value shall be immediately transmitted to the aircraft using the addressed link modification procedures of Section 3.3.2.3.2.3.2.1.

10. The operative_GNIp shall cease MbB operations for the aircraft in question after operative_TMbB seconds

3.3.3.3.3.4 Former_GNIp Requirements

The former_GNIp shall perform the following actions upon receipt of a message from the operative_GNIp indicating that MbB operations are to begin for an aircraft.

1. The former_GNIp shall supercede any existing switching information involving the aircraft with the more recent information.

2. The former_GNIp shall activate the former_TMbB timer and shall delay the generation of a Leave Event Message until the former_TMbB timer expires (see Note below).

3. The former_GNIp shall confirm the receipt of the message with the new (operative) GNIp.

4. The former_GNIp shall compress any packets addressed to the aircraft as required, and send the resulting compressed packet and corresponding frames to the operative_GNIp. The ground subnetwork address field in the frame header is set to the value associated with the former_GNIp.

5. The former_GNIp shall de-encapsulate frames received from the operative_GNIp, decompress the resulting packets, and deliver the uncompressed packet to the local ATN router associated with the former_GNIp.

6. The former_GNIp shall cease MbB operations after former_TMbB seconds.

Note: While the ATN router is initializing using the operative_GNIp, the ATN will be advertising one path to *the aircraft. This will be the path through the former_GNIp. During this time, any data transmitted to the aircraft from any location in the ATN will be forwarded to the ATN router connected to the former_GNIp, which in turn will deliver the data to the operative_GNIp. When IDRP has finished initializing, and the former_TMbB timer has not expired, two paths to the aircraft will be advertised throughout the ATN; one using the ATN router attached to the former_GNIp, the other the ATN router attached to the operative_GNIp. Each path will have a different quality of service associated with it, distinguished by the path distance, or hop count. For this reason, messages to be sent to the aircraft and originating in a control center associated with the operative_GNIp will be sent to the ATN router attached to the operative_GNIp. Because, the hop count will be at least one less than that of the path to the ATN router attached to the former_GNIp. Most, if not all, ATC messages will thus be using the operative_GNIp when the former_TMbB timer expires. When the timer does expire, the path associated with the former_GNIp will be withdrawn, as a result of the generation of a Leave Event Message by the former_GNIp. At this point, all data will use the operative_GNIp, as its associated ATN router is the only one being advertised as capable of reaching the aircraft in question.*

3.3.3.3.4 Recommended MbB Parameter Values

Table 3-91 documents the timing parameter range, increment and default values of the system timers used in the MbB operations. These timers shall be implemented so as to allow for the range, incremental and default values as indicated.

Table 3-91: Recommended MbB Parameter Values

	Minimum Value	Maximum Value	Increment	Default Value	Units
aircraft_TMbB	0	7200	1	300	Seconds
operative_TMbB	0	7200	1	360	Seconds
former_TMbB	0	7200	1	420	Seconds

Note: *The value of the aircraft_TMbB timer must be larger than the expected time it takes the IDRP protocol to initialize and for the subsequent new router to be advertised throughout the ATN. The relationship of the 3 timers must be as follows.*

operative_TMbB>>former_TMbB>>aircraft_TMbB

Continued switching operation by the GNIps after IDRP has initialized is not detrimental to the system. All CLNP packets will be routed correctly, if not efficiently. Thus, the operative_TMbB and former_TMbB timers' primary use is to flush the involved GNIps switching tables of dated information.

3.3.3.4 Router Interface Recommendation

The subnetwork should forward ~~pertinent XIDs~~ to the router only those XIDs requiring specific router assistance, so as to prevent the need for the router to communicate additional information as separate messages and incur additional overhead.

3.3.4 VDL Mode 3 SNDCF Introduction

Aircraft shall support the raw interface and one or both SNDCFs with and without compression. The first type of SNDCF is ISO 8208 based and corresponds to that described in the ATN SARPs for mobile SNDCF. Procedures for this SNDCF are defined in Section 3.3.4.1. The second type of SNDCF, denoted frame-based SNDCF, shall use the procedures defined in Section 3.3.4.2.

Note: *The SNDCF is termed frame-based because it uses the VDL Mode 3 frames without the need for an additional protocol (viz. ISO 8208 SNDCF) to transfer network packets. ~~The~~ VDL Mode 3 achieves independence from the network protocol by identifying the payload of each frame. Upon receipt of a frame, the payload field is examined and control is passed to the protocol identified.*

3.3.4.1 The ISO 8208 SNDCF Interface

VDL Mode 3 shall support the ISO 8208 SNDCF for mobile subnetworks as defined in Appendix J.

3.3.4.2 The Frame-Based SNDCF Interface

The interface used between the network layer and the VDL Mode 3 frame-based SNDCF shall be a local issue. The interface shall be capable of indicating (1) the network protocol being used to transfer data to the remote peer and (2) whether the network packet presented to the VDL system is to be transferred as a broadcast frame or as a unicast (point-to-point) frame. In the case of a unicast frame, the address of the destination shall be provided as part of the SNDCF interface procedures. When the destination is an aircraft, the address provided must be specific enough to allow a one-to-one conversion to the 24-bit aircraft station address used internally by VDL Mode 3.

3.3.4.3 The ATN Frame Mode SNDCF

~~The~~ VDL Mode 3 shall support the ATN Frame Mode SNDCF for mobile subnetworks as defined in the ICAO Doc 9705 (3rd edition), Sub-Volume V Section 5.7.8.

3.3.4.2.1 Frame-Based SNDCF Support for Broadcast & Unicast Network Packets

The frame-based SNDCF shall be capable of transferring to its remote peer both broadcast and unicast network data. Network data identified as broadcast shall be sent using the frame broadcast address. In the case of uplink traffic, network data identified as unicast shall be sent with the frame destination address set to the aircraft identifier specified by the frame-based SNDCF interface protocol. Downlink traffic will use the ground station identifier of record as the ground subnetwork address for unicast data.

3.3.4.2.2 ATN Router Support

3.3.4.2.2.1 Join/Leave Events

An aircraft shall indicate that it requires ATN connectivity during net entry using the DLS Control frame as defined in Section 3.3.2.2.3. The GNI, upon notification from an aircraft that ATN router connectivity is required, shall perform a join event for that aircraft with the local ATN router. When an aircraft leaves the jurisdiction of a GNI, a leave event shall occur both in the avionics and ground VDL Mode 3 equipment.

3.3.4.2.2.2 Payload Identification

When ATN connectivity is in effect the VDL Mode 3 frame-based SNDCF shall be capable of transferring all types of CLNP and ISH packets. When transferring CLNP or ISH packets the procedures of Appendix K shall be used to identify each frame payload.

3.3.4.2.2.3 Disposition of CLNP and ISH Packets

When ATN connectivity has been specified during the net entry procedures, all CLNP and ISH network packets received by the SNDCF from its remote peer(s) shall be transferred to the local ATN router.

3.3.4.2.2.4 ISH Packets

ES-IS or IS-IS packets presented to the VDL Mode 3 system shall be transferred as broadcast or unicast packets as signaled by the ATN router.

3.3.4.2.2.5 CLNP Compression

Compression of CLNP packets within the frame-based SNDCF shall be supported. Compression of CLNP packets shall be performed whenever ATN connectivity is specified and shall be performed according to the procedures defined in Appendix K. Compression shall be performed on both broadcast and unicast packets, and the use of compression shall be signaled during net entry.

3.3.5 Voice Unit

3.3.5.1 Services

The Voice Unit shall provide for a transparent, half duplex, "push-to-talk" audio and signalling interface between the user and the VDL. Two separate mutually exclusive voice circuit types shall be supported.

- Dedicated circuits: This shall provide service to a specific user group on an exclusive basis with no sharing of the circuit with other users outside the group. Access shall be based on a "listen-before-push-to-talk" discipline.

- Demand assigned circuits: This shall provide voice circuit access that is arbitrated by the ground station in response to an access request received from the aircraft station. This type of operation shall allow dynamic sharing of the channel resource increasing trunking efficiency.

3.3.5.1.1 Priority Access

The Voice Unit operation shall support a priority override access via pre-emption only for authorized ground users.

3.3.5.1.2 Message Source Identification

The Voice Unit operation shall support notification to the user of the source of a received message (i.e., whether the message originated from an air or ground station).

3.3.5.1.3 Coded Squelch

The Voice Unit shall support a coded squelch operation that offers some degree of rejection of undesired cochannel voice messages based on the burst time of arrival.

3.3.5.1.4 Urgent Downlink Request (UDR) Signaling

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The Voice Unit shall support signaling whereby the aircraft station can notify the ground station user of an urgent desire to access the voice channel, when the voice channel is otherwise occupied.

3.3.5.2 Speech Encoding

The Voice Unit shall analyze, encode and forward error correct the user's speech at a total bit rate of 4800 bps.

3.3.5.2.1 Speech Encoding Algorithm

The Voice Unit shall incorporate and default to the Advanced Multi-Band Excitation (AMBE) vocoder algorithm, version AMBE-ATC-10, from Digital Voice Systems, Incorporated (DVSI), or equivalent vocoder, for speech compression unless commanded otherwise.

Notes:

1. *The AMBE algorithm is subject to patents. See SARPs, Annex 10, Vol. III, part 1 Section 6.8.2 for more details.*

   Comment: The algorithm must use a voice frame size compatible with the TDMA frame of 120 ms.

2. *The FEC parity bits are included in the 4800 bps transmission rate.*

3.3.5.2.2 Voice Burst Framing

Exactly six (6) voice frames shall be transmitted in a single V/D (voice) burst during full rate operations (TS1 and TS3).

3.3.5.2.3 Vocoder Frame Bit Ordering

The 96 bits of the vocoder frame shall be ordered as follows:

For the DVSI VC-20 ATC-10B implementation, the vocoder encoder frame shall consist of the concatenation of twenty-four 4 bit words output from the vocoder board. For each 4-bit word the msb shall be transmitted first. The first 4-bit word output from the vocoder decoder board shall be transmitted first. The VC-20 ATC-10B vocoder decoder frame shall consist of the concatenation of twenty-four 4 bit words input to the vocoder board. The first 4-bits in the 96-bit vocoder frame received shall be the first 4-bit word of that frame. The first bit in each 4-bit word shall be the msb. For the VC-20 ATC-10B implementation,

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the 4-bit control bytes which precede each vocoder frame shall not be considered part of the 96-bit vocoder frame.

All other implementations shall conform to this bit ordering.

Note: Implementers are advised to contact Digital Voice Systems, Incorporated to ensure correct bit ordering if additional guidance is required.

~~The 96 bits of the vocoder frame shall be ordered as follows:~~
~~For the DVSI VC-20 ATC-10B implementation, the vocoder encoder frame shall consist of the concatenation of 4-bit words output from the vocoder board each transmitted msb first. The VC-20 ATC-10B vocoder decoder frame shall consist of the concatenation of twenty-four 4-bit words input to the vocoder board each received msb first. For the VC-20 ATC-10B implementation, the 4-bit control bytes which precede each vocoder frame shall not be considered part of the 96-bit vocoder frame.~~

~~All other implementations shall conform to this bit ordering.~~

~~*Note: Implementers are advised to contact Digital Voice Systems, Incorporated to ensure correct bit ordering if additional guidance is required.*~~

3.3.5.3 Parameters

The net parameters listed in this section shall be used to control the operation of the Voice Unit.

3.3.5.3.1 Group ID

For receive, the Group ID shall be used to control squelch operation in order to filter out any received V/D (voice) bursts which do not match the Group ID provided by the LME upon net entry.

For transmit, the Header segment of the V/D (voice) burst shall be encoded with the Group ID provided by the LME upon net entry.

If the net entry procedure has not been executed, the value of Group ID shall be the same as the value of Slot ID upon net initialization.

3.3.5.3.2 Squelch Window

The squelch window shall be used to control squelch operation in order to allow the Voice Unit to reject undesired V/D (voice) bursts based on their timing.
The coding and use of the squelch window shall be as provided in Section G.2.1.7.

3.3.5.3.3 Algorithm Version Number

The XID parameter per Table 3-71 shall be used if the default is not used.

3.3.5.4 Description of Procedures

3.3.5.4.1 Link Establishment

3.3.5.4.1.1 Link Initialization

Upon Net Initialization (Section 3.3.2.3.2.1.1), the aircraft LME shall provide the Voice Unit with the net parameters as part of the LME's net initialization procedure. These parameters shall be the Slot ID and Squelch window.

Note: For net initialization directly from TS0 to TS3, there will be no Slot ID information and the Squelch window will be wide open.

~~Upon Net Initialization (Section 3.3.2.3.2.1.1), the aircraft LME shall provide the Voice Unit with the net parameters as part of the LME's net initialization procedure. These parameters shall be the Slot ID and Squelch window.~~

3.3.5.4.1.2 Net Entry

Upon net entry, the aircraft LME shall provide the Voice Unit the Local User ID parameter.

3.3.5.4.2 Timing

Voice frames, on which the analysis and synthesis functions are based, shall be synchronized to the timing of V/D (voice) burst transmission. When receiving a speech transmission, the Voice Unit shall derive voice frame timing from the received V/D (voice) bursts.

3.3.5.4.2.1 Transmit Delay

The delay between speech input and output of the associated V/D (voice) burst shall be less than 175 ms. This delay is measured from the input of the audio signal to the radio to the beginning of the transmission of the user data for the first vocoder frame in the TDMA frame.

> Note: *This delay budget includes up to 35 ms additional delay for ground network functions, such as modem buffering and ground telecommunications delay. It is recognized that some ground implementations may exceed this; however, studies have indicated that an additional 80 ms of delay can be incurred without significant impact to air traffic control operations.*

3.3.5.4.2.2 Receive Delay

The delay between the reception of the V/D (voice) burst and the output of speech shall be less than or equal to 40 ms. The speech shall be

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delayed sufficiently to handle the maximum variation in propagation delays in combination with maximum clock timing drift to ensure that the vocoder synthesis clock will remain a constant period throughout the PTT cycle. This delay is measured from the reception of the first bit of the vocoder user data in a TDMA frame to the point at which that audio begins being played through the user's output device (e.g., speaker, headset).

> Note: *The delay budget includes up to 35 ms additional delay for ground network functions, such as modem buffering and ground telecommunications delay. It is recognized that some ground implementations may exceed this, however, studies have indicated that an additional 80 ms of delay can be incurred without significant impact to air traffic control operations.*

3.3.5.4.3 Voice Transmit Function

Upon PTT activation, the voice unit shall set the Request-to-Send (RTS) flag to notify the MAC sublayer that the voice unit would like to transmit. The voice unit shall also check the Cleared-to-Send (CTS) flag (set by the MAC sublayer, see Section 3.3.2.1.4.2) to determine if the channel is available. The timing of the CTS flag is described in Section 3.3 2.1.4.2. If the channel is available (i.e., CTS flag set), the voice unit shall transmit the V/D (voice) burst. If, upon PTT, the channel is occupied (CTS flag cleared), the user is notified. The final V/D (voice) burst transmitted as a result of release of PTT shall be indicated by setting the EOM flag in the Header Segment of the burst.

~~Upon PTT activation, the voice unit shall set the Request-to-Send (RTS) flag to notify the MAC sublayer that the voice unit would like to transmit. The voice unit shall also check the Cleared-to-Send (CTS) flag to determine if the channel is available. For non-3T configurations, the MAC sublayer shall set the CTS flag when the Voice Signal field of the uplink beacon indicates Voice channel idle and either the V/D (voice) burst in the previous TDMA frame was not present, or the V/D (voice) header indicated an EOM. Otherwise the CTS flag shall be cleared. The setting of the CTS flag for each TDMA frame shall coincide with the MAC timing associated with when the V/D (voice) burst is to be transmitted per Tables 3-54, 3-55, and 3-56 as appropriate. If the channel is available (i.e., CTS indication set), the voice unit shall transmit the V/D (voice) burst. If, upon PTT, the channel is occupied (CTS flag cleared), the user shall be notified. The final V/D (voice) burst transmitted as a result of release of PTT shall be indicated by setting the EOM flag in the Header Segment of the burst.~~

3.3.5.4.3.1 Demand-Assigned Circuits

For the 3T configuration, setting the RTS flag shall cause the MAC layer to generate a voice Reservation Request message. When the corresponding response is received, the CTS flag shall be set, signalling when the speech should be transmitted. The CTS flag shall signal during every TDMA frame to provide timing synchronization with the assigned user group.

3.3.5.4.3.2 Vocoder Processing

If the Voice Unit is notified that it is to operate in the truncated voice mode, the Voice Unit shall truncate the data normally contained in the V/D (voice) burst as indicated below.

3.3.5.4.3.2.1 Truncated Mode Encoding

The Voice Unit shall reduce the rate of the clocking signal to the vocoder to 5/6 of its normal rate, thereby reducing the output data to a 4000 bps rate.

Note: This has the effect of increasing the voice frame size to 24 ms for truncated operation and only generating five vocoder frames per TDMA frame.

3.3.5.4.3.2.2 Truncated Mode Decoding

The Voice Unit shall decode the truncated voice mode bursts and regenerate speech.

Upon detection that the received V/D (voice) burst is a TS2 burst, the Voice Unit should reduce the rate of the clocking signal to the vocoder to 5/6 of its normal rate to process the burst, thereby allowing the synthesis operation to reproduce the output speech from a 4000 bps rate.

Notes:

1. *This has the effect of increasing the voice frame size to 24 ms for truncated operation and only generating five vocoder frames per TDMA frame.*

2. *The specific decode algorithm for the truncated voice mode operation is listed as a recommendation only, so that vendors might have the flexibility to improve upon the performance of the system. However, they must still comply with the encoding format for interoperability reasons.*

3. *Some implementations may take more time for the clock to stabilize after being slewed than is available to maintain data flow. This may incur clipping of the first voice frame, while the clock stabilizes.*

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3.3.5.4.3.2.3 Truncated Mode Formatting

The Voice Unit shall delay transmission of truncated bursts by 16 symbol periods relative to the nominal CTS signal.

Note: This allows for 16 symbol periods of positive or negative timing drift.

The Message ID (MID) field (Section G.2.1.1) of the V/D (voice) burst header shall be set to Downlink voice~~:~~, TS2, to indicate to the receiver that the burst is truncated.

If the Voice Unit is notified that it is to operate in normal or free running mode, the voice unit shall transmit full length V/D (voice) bursts. In normal mode, the MID field of the V/D (voice) burst header shall be set to Uplink voice for ground ~~VDL~~ station and to Downlink voice~~:~~, TS1, for the aircraft ~~VDL~~station. In free running mode, the MID field of the V/D (voice) burst header shall be set to Downlink voice~~:~~, TS3. The Voice Unit shall transmit the bursts at the nominal CTS signal.

3.3.5.4.3.3 Access Pre-emption

If the CTS flag indication is lost during transmission (signaling a ground pre-emption), the voice unit shall cease transmitting and shall process any received V/D (voice) bursts. The ability to transmit voice after the CTS flag is cleared during a transmission shall be inhibited until PTT is reasserted by the user (after which the voice access rules of Table 3-61 need to be reapplied).

Note: Since TS2 and TS3 users cannot hear the ground station, they cannot be overridden by the ground station. This aircraft RF channel unblocking capability is intended to prevent one of these users from interfering with the proper voice operation of the sector.

~~If the CTS indication is lost during transmission (signalling a ground pre-emption), the voice unit shall cease transmitting and shall process any received V/D (voice) bursts. The ability to transmit voice shall be inhibited until PTT is reset by the user.~~

3.3.5.4.3.4 Urgent Downlink Request (UDR)

When the CTS indication is cleared and upon user command, the MAC sublayer shall formulate a Reservation Request M burst message (or Poll Response M burst message, as appropriate) setting the Voice Request field (Section G.2.10.3) to 'Request Priority Access' and shall transmit the M burst message at the next available opportunity. The slots used for sending and retransmitting the urgent/priority message are chosen using the same rules that are used for making a data reservation request. The aircraft station will continue sending the message until it receives a RACK.

Note: Sending of a Reservation Request with the Voice Signal field indicating 'No Request' is used to cancel pending Urgent Downlink Requests.

3.3.5.4.3.4.1 Urgent Downlink Request Not Supported

If the Supported Options message or acknowledging RACK indicates Urgent Downlink Request is not supported, the aircraft radio shall provide an indicator for the user that the request has failed. Further attempts to transmit Urgent Downlink Request shall be inhibited while the aircraft remains in that net.

3.3.5.4.3.5 Anti-blocking

If an aircraft radio has its PTT keyed and CTS is cleared (indicating the channel is busy), voice transmission shall be inhibited until PTT is reasserted by the user (after which the voice access rules of Table 3-61 need to be reapplied). Upon user command, the aircraft station shall unblock the cleared CTS flag when the cleared flag is due to the channel being occupied by TS2 or TS3 voice activity.

Notes:

1. *The purpose of this requirement is to prevent a second user from transmitting a partial communication immediately following the end of transmission of another user, which could lead listeners to misunderstand the communications.*
2. As for the ability to disable the transmission inhibit, Table 3-61 is still applicable to determine whether the transmitter is allowed to output to the voice channel.

3.3.5.4.4 Voice Receive Function

3.3.5.4.4.1 Pre-processing

3.3.5.4.4.1.1 Source Filtering

The Squelch Window parameter shall be applied as specified by the LME. If the voice burst is outside the squelch window defined in Table 3-92 for 4-slot configurations and Table 3-93 for 3-slot configurations, the burst shall be considered to be co-channel interference and shall be suppressed.

Table 3-92. Source Filtering Squelch Window Matrix for 4-Slot Configurations

	Airborne Receiver State Squelch Window (Note 1)			Ground Receiver State Squelch Window (Note 1)
State Message Type	TS1 (Note 2)	TS2 (Note 2, Note 3)	TS3 (Note 5)	TS1 (Note 2)
Uplink voice	-1 to +1	-33 to +1	Wide Open	NA
Downlink voice: TS1	-2 to +4(n+1)	-34 to +4(n+1)	Wide Open	-1 to +(4n+3)
Downlink voice: TS2	-2 to +4(n+9)	-34 to +4(n+9)	Wide Open	-1 to +(4n+35)
Downlink voice: TS3	Wide Open (Note 4)	Wide Open (Note 4)	Wide Open	Wide Open (Note 4)

Note 1. Each squelch window is defined relative to the nominal burst time in symbols
Note 2. n = Squelch Window parameter
Note 3. If n is unknown, then the default value is 6
Note 4. Receive any such message with "correct" Group ID if not already receiving a voice message

Note 5. In this column, "Wide Open" implies that an airborne radio will receive voice messages without regard to Group ID based on the rules defined in Section 3.3.2.1.4.2.2.

Table 3-93. Source Filtering Squelch Window Matrix for 3-Slot Configurations

	Airborne Receiver State Squelch Window (Note 1)			Ground Receiver State Squelch Window (Note 1)
State / Message Type	TS1 (Note 2)	TS2 (Note 2, Note 3)	TS3 (Note 5)	TS1 (Note 2)
Uplink voice	-1 to +1	-33 to +1	Wide Open	NA
Downlink voice: TS1	-2 to +8(n+1)	-34 to +8(n+1)	Wide Open	-1 to +(8n+7)
Downlink voice: TS2	-2 to +8(n+5)	-34 to +8(n+5)	Wide Open	-1 to +(8n+39)
Downlink voice: TS3	Wide Open (Note 4)	Wide Open (Note 4)	Wide Open	Wide Open (Note 4)

Note 1. Each squelch window is defined relative to the nominal burst time in symbols
Note 2. n = Squelch Window parameter
Note 3. If n is unknown, then the default value is 7
Note 4. Receive any such message with "correct" Group ID if not already receiving a voice message

Note 5. In this column, "Wide Open" implies that an airborne radio will receive voice messages without regard to Group ID based on the rules defined in Section 3.3.2.1.4.2.2.

~~The Squelch Window parameter shall be applied as specified by the LME. If the voice burst is outside the squelch window defined in Table 3-92 for 4-slot configurations and Table 3-93 for 3-slot configurations, the burst shall be assumed to be co-channel interference and shall be suppressed.~~

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~~Table 3-92: Source Filtering Squelch Window Matrix for 4-Slot Configurations~~

	~~Aircraft Receiver State Squelch Window (Note 1)~~			~~Ground Receiver State Squelch Window (Note 1)~~
~~State~~ ~~Message Type~~	~~TS1 (Note 2)~~	~~TS2 (Note 2, Note 3)~~	~~TS3~~	~~TS1 (Note 2)~~
~~Uplink voice~~	~~-1 to +1~~	~~-33 to +1~~	~~Wide Open (Note 4)~~	~~NA~~
~~Downlink voice: TS1~~	~~-2 to +4(n+1)~~	~~-34 to +4(n+1)~~	~~Wide Open (Note 4)~~	~~-1 to +(4n+3)~~
~~Downlink voice: TS2~~	~~-2 to +4(n+9)~~	~~-34 to +4(n+9)~~	~~Wide Open (Note 4)~~	~~-1 to +(4n+35)~~
~~Downlink voice: TS3~~	~~Wide Open (Note 4)~~	~~Wide Open (Note 4)~~	~~Wide Open (Note 4)~~	~~Wide Open (Note 4)~~

~~Note 1: *Each squelch window is defined relative to the nominal burst time in symbols*~~
~~Note 2: *n = squelch window parameter*~~
~~Note 3: *If n is unknown, then the default value is 6. n=7 is not a valid Squelch Window parameter.*~~
~~Note 4: *Receive any such message with "correct" group ID if not already receiving a voice message*~~

~~Table 3-93: Source Filtering Squelch Window Matrix for 3-Slot Configurations~~

	~~Aircraft Receiver State Squelch Window (Note 1)~~			~~Ground Receiver State Squelch Window (Note 1)~~
~~State~~ ~~Message Type~~	~~TS1~~ ~~(Note 2)~~	~~TS2~~ ~~(Note 2, Note 3)~~	~~TS3~~	~~TS1~~ ~~(Note 2)~~
~~Uplink voice~~	~~-1 to +1~~	~~-33 to +1~~	~~Wide Open (Note 4)~~	~~NA~~
~~Downlink voice: TS1~~	~~-2 to +8(n+1)~~	~~-34 to +8(n+1)~~	~~Wide Open (Note 4)~~	~~-1 to +(8n+7)~~
~~Downlink voice: TS2~~	~~-2 to +8(n+5)~~	~~-34 to +8(n+5)~~	~~Wide Open (Note 4)~~	~~-1 to +(8n+39)~~
~~Downlink voice: TS3~~	~~Wide Open (Note 4)~~	~~Wide Open (Note 4)~~	~~Wide Open (Note 4)~~	~~Wide Open (Note 4)~~

~~Note 1: *Each squelch window is defined relative to the nominal burst time in symbols*~~
~~Note 2: *n = squelch window parameter*~~
~~Note 3: *If n is unknown, then the default value is 7*~~
~~Note 4: *Receive any such message with "correct" group ID if not already receiving a voice message*~~

3.3.5.4.4.1.2 Vocoder Processing

A received V/D (voice) burst with MID field of Uplink voice~~,~~ with a Downlink voice~~:~~ of TS1~~,~~ or~~ Downlink voice:~~ TS3 shall be processed at the normal vocoder rate of 4800 bps. A received V/D (voice) burst with MID field of Downlink voice~~:~~, TS2, shall be processed at the truncated rate of 4000 bps.

3.3.5.4.4.1.3 Source Identification

The Voice Unit shall indicate the source (ground user or aircraft user) of the received voice message based on the V/D (voice) burst header. ~~The user shall be notified of the source of the received voice message (ground or air) based on the entire Message ID field.~~

3.3.5.4.4.2 Voice Synthesis

The Voice Unit shall buffer and delay the speech sufficiently to maintain a constant period for the analysis and synthesis clocks of the vocoder regardless of the varying propagation delay, and relative clock timing drifts between transmitter and receiver.

If bursts are missing, the Voice Unit shall slowly attenuate the speech to silence (or pseudo-noise). The voice unit shall resume normal operation when receipt of the V/D (voice) bursts continues.

3.4 Ground Transmitter

Only those portions of the ground transmitter specification that are different from the airborne transmitter will be included here. Omitted portions shall be the same as detailed for the airborne transmitter.

3.4.1 Ground Transmitter Power

The Ground Transmitter shall be capable of a minimum of 15 watts of RF output power.

Notes:

1. *15 watts of transmitter output power is required to provide equivalent link margin at 180 FL and 100 nmi as the present DSB-AM analog voice system.*

2. *System validation may determine that greater than 15 watts of transmitter power is required to insure minimum BER performance (Section 2.4.2) with sufficient link availability (Section 3.7.4).*

3.4.2 Transmitter Duty Cycle

The ground transmitter shall be capable of operating with a long term duty cycle of 100%.

3.5 Uplink

3.5.1 Uplink Channel Characteristics

3.5.1.1 Doppler Characteristics

3.5.1.1.1 Doppler Shift

Relative velocities from 0 to 1200 knots between transmitter and receiver must be accommodated. The corresponding Doppler shifts will range between ± 243 Hz at a radio carrier frequency of 118 MHz and range between ± 282 Hz at 137 MHz, with Doppler shift proportional to the carrier frequency.

Note: *For air-ground links, the Doppler shift of the received carrier can be either positive or negative with respect to the transmitted carrier, depending upon whether an aircraft is approaching or receding from a ground LME. For air-to-air links, the sign of the Doppler shift depends upon whether two aircraft are approaching or receding from each other.*

3.5.1.1.2 Doppler Rate

Relative velocities from 0 to 1200 knots between transmitter and receiver must be accommodated. The corresponding Doppler rate will be 0 to 7.8 Hz/s for a 2g aircraft turn at a radio carrier frequency of 137 MHz.

Notes:

1. *For an 850 knot aircraft overflying a ground LME at 40,000 ft, the maximum Doppler rate at the point of closest approach is -10 Hz/s at 137 MHz. An aircraft traveling at 150 knots coming within 500 ft of a ground LME at the point of closest approach produces a maximum Doppler rate of -18 Hz/s.*

2. *In aircraft turns, the maximum rate of change of Doppler shift occurs when the aircraft acceleration is directed along the communication link line of sight. Doppler rate is proportional to the acceleration. For a 2g aircraft turn at 137 MHz, Doppler rate on an air-ground link varies from 0 to 7.8 Hz/s and can be either positive or negative. On air-to-air links, the maximum Doppler rate is doubled to 15.5 Hz/s and can also be either positive or negative.*

3. *In constant velocity flight, the changing angle between the aircraft flight path and the communication link line of sight causes a rate of change of Doppler shift. Doppler shift monotonically decreases in this situation, following the familiar "S-curve" where Doppler shift is positive as the aircraft approaches the ground LME, goes through zero at the point of closest approach, and becomes negative as the aircraft recedes from the ground LME.*

3.5.1.1.3 Delay and Doppler Spread

Notes:

1. *The worst-case delay spread for air-ground paths is approximately 200 microseconds, caused by diffuse earth reflection. On air-to-air paths, larger values of delay spread are possible, up to 1 millisecond or more, due to diffuse earth reflection.*

2. *Scattering from the tips of rotor craft blades can generate large worse-case Doppler spreads, up to approximately 500 Hz, on VHF air-ground links.*

3. *These worst-case delay and Doppler spreads occur only in certain geometries and, therefore, may be observed infrequently.*

3.5.1.2 Signal Fading

General information on signal fading is provided in Appendix B.

3.5.1.2.1 Fast Fading with Rotary Wing Aircraft

> Note: *The effect of rotor blades and propellers on communication link performance is of particular interest in characterizing "fast" multi-path fading. See Section 3.2.1.3.2 and Appendix B2.0 of Appendix B. Typical commercial helicopters can have 2 to 5 blades that operate at from 200 to 550 rpm. The effects in the VHF spectra are two-fold: near-field influence of the current distributions on radiating elements, and multi-path and blockage of the primary signal. The amplitude and phase disturbances on the received signals can introduce significant link errors. An analysis and measurement study should be performed.*

3.5.1.3 Airborne Noise Environment

> Note: *Specific information on the expected airborne noise environment common to all platforms may be contained in the separate Minimum Operational Performance Standards (MOPS) document.*

3.5.1.4 Cochannel Interference

3.5.1.4.1 VDL Mode 2

The data performance, as specified in Section 2, shall be provided when the desired to undesired signal ratio is no less than 20 dB.

3.5.1.4.2 VDL Mode 3

The voice and data performance, as specified in Section 2, shall be provided when the desired to undesired signal ratio is no less than 20 dB.

3.5.2 Typical Uplink Power Budget

Uplink Power Budgets, shown in Table 3-94, are calculated to determine potential service volume link performance margins. These power budgets are calculated based on the following assumptions and on the methodology and equations discussed in Appendix L:

a. Ground transmitter power is 15 Watts (25 Watts for long range)

b. Ground transmitter-to-antenna cable loss is 3 dB (2 dB for long range)
c. Ground antenna gain is 2.1 dBi near the horizon (6 dBi for long range)
d. Aircraft antenna gain is –4 dBi over the angular region of interest
e. Aircraft antenna-to-receiver cable loss is 3 dB
f. Implementation loss is 2.2 dB, nominally allocated 1.0 dB for the transmitter and 1.2 dB for the receiver
g. Receiver Noise Figure is 14 dB
h. Loss due to raised cosine transmit filter is 1.8 dB
i. The theoretical E_b / N_0 required for a bit error rate of 10^{-3} is 13 dB
j. External man-made noise figure is 20 dB (10 dB for long range)

> *Note 1: 3 dB is assumed as a typical aircraft antenna-to-aircraft receiver/transmitter cable loss, even though some isolated existing aircraft have backup radio installations with cable loss up to 5.5 dB.*

Table 3-94 shows uplink power budgets at various ranges between ground transmitter site and aircraft, and assumes a $1/R^2$ free-space path loss. At lower elevations and longer ranges, the total path loss will exceed the free space path loss. Values of excess path loss can be estimated using a variety of standardized computer programs that consider the effects of varying radio refractivity over time.

Table 3-95 shows excess path loss as a function of flight level and aircraft to ground range, calculated based on the Johnson-Gierhart model computer program. These calculations are based on a ground antenna height of 50 feet, and represent 95th percentile excess path loss values. That is, the values of excess path loss can be expected to be less than or equal to the values given in the table 95% of the time.

Table 3-96 presents a combination of the data from Table 3-94 and Table 3-95. This results in the estimated 95th percentile VDL link margin. Consistent with the interpretation of the values in Table 3-95, users can expect a link margin that is arithmetically larger than the values in Table 3-96 95% of the time.

> *Note 2: Uplink and downlink (see Section 3.9.2) power budgets are asymmetrical because the minimum detectable signal is different for ground and airborne receivers. This difference in minimum detectable signal occurs because receiver noise figures and antenna gains are different between ground and airborne radios. Because external noise is not negligible compared to receiver noise in the 117.975-137 MHz band, a system noise figure calculation is required (see Appendix L). These factors differ between airborne and ground radios.*

Table 3-94: Uplink Power Budget for VHF Digital Radio

1	Air-to-Ground Slant Range (nmi)	40	80	110	160	200
2	Ground Antenna Height (ft)	50.0	50.0	50.0	50.0	50.0
3	Transmitter Power (dBm)	41.8	41.8	41.8	44.0	44.0
4	Transmit antenna gain (dBi)	2.1	2.1	2.1	6.0	6.0
5	Transmit Line losses (dB)	3.0	3.0	3.0	2.0	2.0
6	Transmit EIRP (dBm)	40.9	40.9	40.9	48.0	48.0
7	Free space Loss (dB)	112.6	118.6	121.4	124.6	126.6
8	Excess Path Loss (dB) (Note 1, 2)	0.0	0.0	0.0	0.0	0.0
9	Receive antenna gain (dBi)	-4.0	-4.0	-4.0	-4.0	-4.0
10	Receive Line losses (dB)	3.0	3.0	3.0	3.0	3.0
11	Received Signal Level (dBm)	-78.7	-84.7	-87.5	-83.6	-85.6
12	Receiver Noise Figure (dB)	14.0	14.0	14.0	14.0	14.0
13	Receiver Noise Power Density (dBm/Hz)	-160.0	-160.0	-160.0	-160.0	-160.0
14	External Noise Figure (dB) (Note 1)	20.0	20.0	20.0	10.0	10.0
15	External Noise Power Density (dBm/Hz)	-154.0	-154.0	-154.0	-164.0	-164.0
16	Receive Line Losses (dB)	3.0	3.0	3.0	3.0	3.0
17	System Noise Temp at Antenna Output (dBK)	46.4	46.4	46.4	42.3	42.3
18	System Noise Temp at Receiver Input (dBK)	43.4	43.4	43.4	39.3	39.3
19	Total system noise power density (dBm/Hz)	-155.2	-155.2	-155.2	-159.1	-159.1
20	Total system noise power in 10.5 kHz(dBm)	-115.0	-115.0	-115.0	-118.9	-118.9
21	Theory Es/No for Spec Block Error Rate (dB)	17.8	17.8	17.8	17.8	17.8
22	Raised Cosine Filter Loss (dB)	1.8	1.8	1.8	1.8	1.8
23	Transmitter Implementation Loss (dB)	1.0	1.0	1.0	1.0	1.0
24	Receiver Implementation Loss (dB)	1.2	1.2	1.2	1.2	1.2
25	Required Es/No (dB)	21.8	21.8	21.8	21.8	21.8
26	Required Receiver Sensitivity (dBm)	-98.0	-98.0	-98.0	-98.0	-98.0
27	Es/No Available (dB)	36.3	30.3	27.5	35.3	33.3
28	Residual System Margin (dB)	14.5	8.5	5.7	13.5	11.5

Notes:

1. See Appendix L for detailed discussion of all link budget entries.

2. Operating frequency of 137 MHz.

Table 3-95: Excess Path Loss 95% Prob 1 Hr. Avg 137 MHz(dB)

	Range (nmi)				
Altitude (ft)	40	80	110	160	200
5000	0.6	16.2	*	*	*
18000	0	0.8	2.7	19.0	*
33000	0	0	0.3	4.0	11.9
45000	0	0	0.1	1.8	5.7
70000	0	0	0	0.2	1.2

* Beyond Line of Sight

Table 3-96: Link Margin (Uplink) in Decibels

	Range (nmi)				
Altitude (ft)	40	80	110	160	200
5000	13.9	-7.7	*	*	*
18000	14.5	7.7	3.0	-5.5	*
33000	14.5	8.5	5.4	9.5	-0.4
45000	14.5	8.5	5.6	11.7	5.4
70000	14.5	8.5	5.7	13.3	10.3

* Beyond Line of Sight

Note 3: Short term fluctuations in the received signal due to time-varying propagation may lead to additional losses of up to 5 dB. The margins shown in this table predict VDL performance equivalent to that of DSB-AM VHF voice communications.

~~3.5.2 Uplink Power Budget~~

~~Uplink Power Budgets, shown in Table 3-94, are calculated to determine potential service volume link performance margins. These power budgets are calculated based on the following assumptions:~~

~~- Ground transmitter power is 15 watts~~
~~- Ground transmitter to antenna cable loss is 3 dB~~
~~- Ground antenna gain of 2.15 dBi (near the horizon)~~
~~- Aircraft antenna gain of -4 dBi (over the angular region of interest)~~
~~- Aircraft antenna to aircraft receiver cable loss of 3 dB~~
~~- Loss due to RC transmit filter is 1.8 dB~~
~~- Ground transmitter Implementation loss allowance is1.0 dB~~
~~- Aircraft receiver Implementation loss allowance is 1.2 dB~~
~~- Minimum E_b/N_o = 13 dB at 10^{-3} BER~~

~~*Note 1: 3 dB is assumed as a typical aircraft antenna to aircraft receiver cable loss, even though some isolated existing aircraft have backup radio installations with cable losses up to 5.5 dB.*~~

~~Table 3-94 shows uplink power budgets at various free space ranges between ground LME transmitter site and aircraft at lower elevations and longer ranges, the total path loss will exceed the free space path loss (given by a simple $1/R^2$ law). Values of excess path loss can be~~

~~estimated using a variety of standardized computer programs, which consider effects of varying radio refractivity over time.~~

~~Table 3-95 shows excess path loss, as a function of flight level and aircraft to ground LME range, calculated based on the Johnson Gierhart model computer program. These calculations are based on a 50 ft. ground antenna height and represent path loss for 95% time availability.~~

~~Table 3-94: Uplink Power Budget for VHF Digital Radio~~

	~~Range (nmi)~~					
	~~40~~	**~~80~~**	**~~110~~**	**~~160~~**	**~~200~~**	
~~Transmit Power (dBm)~~	~~41.76~~	~~41.76~~	~~41.76~~	~~41.76~~	~~41.76~~	
~~Cable Loss – Ground (dB)~~	~~-3~~	~~-3~~	~~-3~~	~~-3~~	~~-3~~	
~~Antenna Gain – Ground (dBi)~~	~~2.15~~	~~2.15~~	~~2.15~~	~~2.15~~	~~2.15~~	
~~Free Space Path Loss (dB)~~	~~-112.57~~	~~-118.59~~	~~-121.36~~	~~-124.61~~	~~-126.55~~	
~~Excess Path Loss (dB)~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	
~~Antenna Gain – Aircraft (dBi)~~	~~-4~~	~~-4~~	~~-4~~	~~-4~~	~~-4~~	
~~Cable Loss – Aircraft (dB)~~	~~-3~~	~~-3~~	~~-3~~	~~-3~~	~~-3~~	
~~Received Power (dBm)~~	~~-78.66~~	~~-84.68~~	~~-87.45~~	~~-90.70~~	~~-92.64~~	
~~Receiver Noise Figure (dB)~~	~~14~~	~~14~~	~~14~~	~~14~~	~~14~~	
~~External Noise Figure (dB)~~	~~20~~	~~20~~	~~20~~	~~20~~	~~20~~	
~~Effective System Noise Figure (dB)~~	~~18.76~~	~~18.76~~	~~18.76~~	~~18.76~~	~~18.76~~	
~~kT_0 (dBm/Hz)~~	~~-174~~	~~-174~~	~~-174~~	~~-174~~	~~-174~~	
~~P_r/N_0 (dBHz)~~	~~76.58~~	~~70.56~~	~~67.79~~	~~64.54~~	~~62.60~~	
~~Baud Rate (dBHz)~~	~~40.21~~	~~40.21~~	~~40.21~~	~~40.21~~	~~40.21~~	
~~E_s/N_0 Before Losses (dB)~~	~~36.36~~	~~30.34~~	~~27.58~~	~~24.32~~	~~22.39~~	
~~Transmitter Implementation Loss (dB)~~	~~1.0~~	~~1.0~~	~~1.0~~	~~1.0~~	~~1.0~~	
~~Receiver Implementation Loss (dB)~~	~~1.2~~	~~1.2~~	~~1.2~~	~~1.2~~	~~1.2~~	
~~Received E_s/N_0 (dB)~~	~~34.16~~	~~28.14~~	~~25.38~~	~~22.12~~	~~20.19~~	
~~Received E_b/N_0 (dB)~~	~~29.39~~	~~23.37~~	~~20.61~~	~~17.35~~	~~15.41~~	
~~Required E_b/N_0 (Ideal) (dB)~~	~~13~~	~~13~~	~~13~~	~~13~~	~~13~~	
~~Required E_b/N_0 (RC Filter) (dB)~~	~~14.80~~	~~14.80~~	~~14.80~~	~~14.80~~	~~14.80~~	
~~Margin (dB)~~	~~14.59~~	~~8.57~~	~~5.81~~	~~2.55~~	~~0.61~~	

~~Assumptions: Man-Made Noise, 137 MHz, No Excess Path Loss, Effective Noise Figure Referred to Receiver Input Terminals. The entries in Table 3-94 are based on assumptions listed in Section 3.5.2 and are subject to further review and refinement.~~

~~Table 3-95: Excess Path Loss (dB) 95% Probability, Hourly Average, 137 MHz~~

~~Altitude (ft.)~~	~~Range (nmi)~~				
	~~40~~	~~80~~	~~110~~	~~160~~	~~200~~
~~5000~~	~~0.6~~	~~16.2~~	~~*~~	~~*~~	~~*~~
~~18000~~	~~0~~	~~0.8~~	~~2.7~~	~~19.0~~	~~*~~
~~33000~~	~~0~~	~~0~~	~~0.3~~	~~4.0~~	~~11.9~~
~~45000~~	~~0~~	~~0~~	~~0.1~~	~~1.8~~	~~5.7~~
~~70000~~	~~0~~	~~0~~	~~0~~	~~0.2~~	~~1.2~~

~~* beyond line of sight~~

~~Table 3-96 data is a combination of the data from Tables 3-94 and 3-95. Table 3-96, therefore indicates the theoretical net link margin expected to be exceeded 95% of the time.~~

~~*Note 2:* *Uplink (see Section 3.9.2) and downlink power budgets are asymmetrical because the minimum detectable signal is different for ground and airborne receivers. This difference in minimum detectable signal occurs because receiver noise figures, and antenna gains are different between ground and airborne radios. Since external noise is not negligible compared to receiver noise in the 117.975 - 137 MHz band, a system noise figure is determined by receiver noise figure, external noise factor, and cable loss, and all these factors can be different between ground and airborne radios.*~~

~~Table 3-96: Link Margin (Uplink) (dB)~~

~~Altitude (ft)~~	**~~Range (nmi)~~**				
	~~40~~	**~~80~~**	**~~110~~**	**~~160~~**	**~~200~~**
~~5000~~	~~13.99~~	~~-7.63~~	~~*~~	~~*~~	~~*~~
~~18000~~	~~14.59~~	~~7.77~~	~~3.11~~	~~-16.45~~	~~*~~
~~33000~~	~~14.59~~	~~8.57~~	~~5.51~~	~~-1.45~~	~~-11.29~~
~~45000~~	~~14.59~~	~~8.57~~	~~5.71~~	~~0.75~~	~~-5.09~~
~~70000~~	~~14.59~~	~~8.57~~	~~5.81~~	~~2.35~~	~~-0.59~~

~~* beyond line of sight~~

~~*Note 3:* *Service volume regions to the right of the double line in Table 3-96 fall outside of the coverage area of a typical installation for both a 10 watt DSB-AM system and the new 15 watt D8PSK digital system. Higher power ground transmitters and/or higher gain antennas will increase the uplink link margins and consequently the range.*~~

3.6 Airborne Receiver

Note: *Implementation of the receiver demodulator can have a significant effect on receiver operational performance. In particular coherent demodulation of the D8PSK signal may adversely affect receiver performance in a fading environment.*

Section 3.6.1 Minimum Detectable Signal (Uplink)

The minimum detectable VHF radio frequency signal impinging upon an airborne antenna which will result in a 10^{-3} BER in the digital transmission shall be $6.22x10^{-12}$ watts/m^2 in the short range case (or $2.49x10^{-12}$ watts/m^2 in the long range case), assuming the values listed in Section 3.5.2.

Note: The uplink calculation in Table 3-97 is based on the (uncorrected) BER of 10^{-3} for both Mode 2 and Mode 3. The ICAO SARPs require a corrected BER of 10^{-4} for Mode 2 data operations. When the effects of the Reed-Solomon encoding/decoding are included to transform the uncorrected BER to the corrected BER, the link margins for Mode 2 operations are reduced by 0.8 dB from those shown in Tables 3-94 and 3-96. When viewed from a packet-error-rate standpoint under the assumption that a packet contains 248 octets of data, the difference in performance may approach 2 dB, with VDL Mode 3 offering the same performance at lower received power levels. The common standard performance of 10^{-3} (uncorrected) BER has been established to simplify the design and qualification of ground and airborne hardware supporting both VDL Modes. System implementers are cautioned to account for the different performance when establishing coverage areas and operational procedures.

Table 3-97 shows the calculations that establish these minimum detectable signal values.

Table 3-97: Minimum Detectable (Uplink) Signal Calculations

	Short Range Case (typically ≤ 110 nmi)	Long Range Case (typically ≥ 160 nmi)	
E_b/N_0 (10^{-3} BER)	13 dB	13 dB	
E_S/E_b	4.77 dB	4.77 dB	
Imp. Loss + RC Loss	4.0 dB	4.0 dB	
E_S/N_0	21.77	21.77	
KT_0	-174 dBm/Hz	-174 dBm/Hz	
Effective Noise Figure	18.76 dB	14.79 dB	
Symbol Rate (R)	40.21 dBHz	40.21 dBHz	
N_0 x R	-115.03 dBm	-119.00 dBm	
Required Receiver Input	-93.26 dBm	-97.23 dBm	
Cable Loss	3.0 dB	3.0 dB	
Antenna Output	-90.26 dBm (9.42×10^{-13} watts)	-94.23 dBm (3.77×10^{-13} watts)	
Antenna Loss	4.0 dBi	4.0 dBi	
Antenna Effective Area*	0.15 m^2	0.15 m^2	
Required Power Density	6.22×10^{-12} watts/m^2	2.49×10^{-12} watts/m^2	
Required Field Strength	48 µV/m	31 µV/m	

*Effective Area $= G\left(\lambda^2 / 4\pi\right)$, with G=(antenna loss)$^{-1}$ and $\lambda = 2.19m$ for 137 MHz.

~~3.6.1 Minimum Detectable Signal (Uplink)~~

~~The minimum detectable VHF radio frequency signal impinging upon an airborne antenna which will result in a 10^{-3} BER in the digital transmission shall be 3.15x10^{-12}watts/m^2, assuming the value assumptions listed in Section 3.5.2, and assuming 0.44 m^2 aircraft antenna effective area.~~

~~Table 3-97 shows the calculation which establishes this minimum detectable signal value.~~

~~Table 3-97: Minimum Detectable (Uplink) Signal Calculation~~

~~E_b/N_0 (10^{-3} BER)~~	~~13 dB~~
~~E_s/E_b~~	~~4.77 dB~~
~~Imp. Loss + RC Loss~~	~~4.0 dB~~
~~E_s/N_0~~	~~21.77 dB~~
~~kT_0~~	~~-174 dBm/Hz~~
~~Effective Noise Figure~~	~~18.76 dB~~
~~Baud Rate (R)~~	~~40.21 dBHz~~
~~N_0 x R~~	~~-115.03 dBm~~
~~Required Receiver Input~~	~~-93.26 dBm~~
~~Cable Loss~~	~~3.0 dB~~
~~Antenna Loss~~	~~4.0 dBi~~
~~Antenna Output*~~	~~-86.26 dBm (2.37 x 10^{-12} watts)~~
~~Antenna Effective Area~~	~~0.38 m^2~~
~~Required Power Density~~	~~6.22 x 10^{-12} watts/m^2~~
~~Required Field Strength~~	~~48 µV/m~~

~~*Output of an idealized lossless, isotropic antenna.~~

3.7 Combined Airborne Receive/Transmit Characteristics

3.7.1 Frequency Stability

The transmitter carrier long-term frequency stability (see Section 1.1.2 for definition) shall be within ± 5 parts per million (ppm).

Note: *This specification assumes that the ground LME transmitter frequency stability is ± 2 ppm. Thus, the end-to-end static frequency tolerance is ± 7 ppm. Then:*

1. *The worst-case carrier frequency offset between a ground and airborne radio allowed by this frequency stability specification is ± 959 Hz at 137 MHz. When combined with the worst-case Doppler shift of ± 141 Hz, a worst-case carrier frequency offset of ± 1100 Hz is possible; and*

2. *The worst-case carrier frequency offset between two airborne radios is ± 2 (685 + 141) = ± 1652 Hz.*

3.7.2 Tuning Time

The transmitter shall be capable of tuning to and operating on any of the 760 25-kHz channels, from 118.000 MHz through 136.975 MHz within 100 ms of the receipt of a command to change frequency/channel.

Note: For VDL Mode 3, the tuning time for an aircraft station is measured starting from entry into TS0 until the radio is capable of receiving M uplink beacons on its new net.

~~The transmitter shall be capable of tuning to and operating on any of the 760 25-kHz channels in simplex operation, from 118.000 MHz through 136.975 MHz within 100 ms of the receipt of the command to change frequency assignments.~~

3.7.3 Airborne Antenna Characteristics

Airborne antennas shall be vertically polarized and provide a radiation pattern omnidirectional in azimuth. The aircraft antenna gains specified here are for the antenna mounted on the airframe and apply equally to transmitting and receiving. When used for transmitting, a VHF antenna shall be capable of operating with a maximum average input power of 50 W.

Over the 117.975 - 137 MHz frequency band, antenna gain near the horizon shall exceed - 4 dBi (decibels relative to an isotropic radiator) over 95% of azimuthal directions.

Near the zenith and nadir, antenna gain shall exceed -12 dBi.

Notes:

1 *It is assumed that an antenna that meets the requirements of DO-186A Sections 2.2.14 and 2.2.15 also meets the requirements stated above.*

2. *3 dB is assumed as a typical aircraft antenna to aircraft receiver cable loss, even though some isolated existing aircraft have backup radio installations with cable losses up to 5.5 dB.*

~~*Note: 3 dB is assumed as a typical aircraft antenna to aircraft receiver cable loss, even though some isolated existing aircraft have backup radio installations with cable losses up to 5.5 dB.*~~

3.7.4 Link Availability

There should be a minimum of 5 dB link margin throughout every service volume to ensure link availability is no worse than the present DSB-AM analog voice system.
~~There shall be a minimum of 5 dB link margin within every service volume to insure link availability no worse than the present DSB-AM analog voice system.~~

Note: *One contribution to overall system availability is link availability. For the purposes of this discussion link availability can be defined as the probability that the link margin for some link in a service volume is positive. In other words, it is the probability that the quality of a given link is acceptable. Failure to provide an acceptable link could result in total loss of communication or a degradation of intelligibility, for example.*

The link power budgets included in Sections 3.5.2 and 3.9.2 estimate the 95% link margin for some representative cases. Zero margin indicates that an acceptable link is available 95% of the time, i.e., the availability is 0.95. The amount of excess margin required depends on a number of factors including, the bit-error-rate (BER) requirements, and the operating environment.

Fading is discussed in some detail in Section B2.0 of Appendix B. Fading causes fluctuations in signal strength and signal phase which create statistical fluctuations, which in turn necessitate excess link margin. The amount of excess needed depends on the statistics of the fading. These statistics, however, depend on the geometry of a given link. For instance, medium-range, high-altitude links will probably experience less fluctuation than long-range links where the line of sight just grazes the earth. To accurately characterize link margin requirements would require a detailed study involving many parameters. In lieu of such a study, a representative signal distribution (e.g., Rician) whose validity is based on past experience may be adequate. This distribution needs to be agreed upon before margin requirements can be determined. Note that more than one distribution could be required if there are disparate environments (e.g., helicopters versus fixed-wing aircraft).

3.8 Airborne Transmitter

3.8.1 Transmitter Power

Nominal Output Power

Transmitter radio frequency (RF) output power shall be 15 watts minimum and 30 watts maximum, delivered into a 50 ohm load. Output power shall be measured during signal transmission not averaged over the time intervals between signal transmissions.

For those aircraft communicating out only to 100 miles, the output power shall be 4 watts minimum.

> Note: *The specification of 15 W assumes a maximum cable loss to the antenna of 3 dB, thus providing 7.5 W into the antenna.*

Transmitter Duty Cycle

Long term transmitter duty cycle shall be a maximum of 20%. A transmitter may transmit continuously (100% duty cycle) for up to thirty five seconds.

3.9 Downlink

Only those portions of the downlink specification that are different from the uplink (see Section 3.5) are included here to the extent that, electromagnetic reciprocity holds. However, there are potential differences; for example, space diversity, with multiple ground sites and/or widely separated ground antennas at the same site, is possible. Omitted portions shall be the same as detailed for the uplink direction.

3.9.1 Downlink Channel Characteristics

3.9.1.1 Ground Noise Environment

> Note: *Specific information on the expected ground noise environment common to all locations will be contained in the separate MOPS document.*

3.9.2 Typical Downlink Power Budget

Downlink power budgets (shown in Table 3-98) are calculated to determine potential service volume link performance margins. These power budgets are calculated based on the following assumptions and on the methodology and equations discussed in Appendix L:

a. Aircraft transmitter power is 15 Watts
b. Aircraft transmitter-to-antenna cable loss is 3 dB
c. Aircraft antenna gain is –4 dBi over the angular region of interest
d. Ground antenna gain of 2.1 dBi near the horizon (6 dBi for long range)
e. Loss due to raised cosine transmit filter is 1.8 dB
f. Implementation loss is 2.2 dB, nominally allocated 1.0 dB for the transmitter and 1.2 dB for the receiver
g. The theoretical E_b / N_0 required for a bit error rate of 10^{-3} is 13 dB

h. External man-made noise figure is 20 dB (13 dB for long range)
i. Receiver Noise Figure is 10 dB.

Note 1: 3 dB is assumed as a typical aircraft antenna-to-aircraft receiver/transmitter cable loss, even though some isolated existing aircraft have backup radio installations with cable loss up to 5.5 dB.

Table 3-98 shows downlink power budgets at various ranges between ground transmitter site and aircraft, and assumes a $1/R^2$ free-space path loss. At lower elevations and longer ranges, the total path loss will exceed the free space path loss.

Table 3-99 presents a combination of the data from Table 3-98 and Table 3-95. This results in the estimated 95th percentile VDL link margin. Consistent with the interpretation of the values in Table 3-95, users can expect a link margin that is arithmetically larger than the values in Table 3-96 95% of the time.

Note 2: Uplink (see Section 3.5.2) and downlink power budgets are asymmetrical because the minimum detectable signal is different for ground and airborne receivers. This difference in minimum detectable signal occurs because receiver noise figures and antenna gains are different between ground and airborne radios. Because external noise is not negligible compared to receiver noise in the 117.975-137 MHz band, a system noise figure calculation is required (see Appendix L). These factors differ between airborne and ground radios.

Table 3-98: Downlink Power Budget for VHF Digital Radio

1	Air-to-Ground Slant Range (nmi)	40	80	110	160	200
2	Ground Antenna Height (ft)	50.0	50.0	50.0	50.0	50.0
3	Transmitter Power (dBm)	41.8	41.8	41.8	41.8	41.8
4	Transmit antenna gain (dBi)	-4.0	-4.0	-4.0	-4.0	-4.0
5	Transmit Line losses (dB)	3.0	3.0	3.0	3.0	3.0
6	Transmit EIRP (dBm)	34.8	34.8	34.8	34.8	34.8
7	Free space Loss (dB)	112.6	118.6	121.4	124.6	126.6
8	Excess Path Loss (dB) (Note 1, 2)	0.0	0.0	0.0	0.0	0.0
9	Receive antenna gain (dBi)	2.1	2.1	2.1	6.0	6.0
10	Receive Line losses (dB)	3.0	3.0	3.0	2.0	2.0
11	Received Signal Level (dBm)	-78.7	-84.7	-87.5	-85.8	-87.8
12	Receiver Noise Figure (dB)	10.0	10.0	10.0	10.0	10.0
13	Receiver Noise Power Density (dBm/Hz)	-164.0	-164.0	-164.0	-164.0	-164.0
14	External Noise Figure (dB) (Note 1)	20.0	20.0	20.0	13.0	13.0
15	External Noise Power Density (dBm/Hz)	-154.0	-154.0	-154.0	-161.0	-161.0
16	Receive Line Losses (dB)	3.0	3.0	3.0	2.0	2.0
17	System Noise Temp at Antenna Output (dBK)	45.4	45.4	45.4	40.0	40.0
18	System Noise Temp at Receiver Input (dBK)	42.4	42.4	42.4	38.0	38.0
19	Total system noise power density (dBm/Hz)	-156.2	-156.2	-156.2	-160.4	-160.4
20	Total system noise power in 10.5 kHz(dBm)	-115.9	-115.9	-115.9	-120.2	-120.2
21	Theory Es/No for Spec Block Error Rate (dB)	17.8	17.8	17.8	17.8	17.8
22	Raised Cosine Filter Loss (dB)	1.8	1.8	1.8	1.8	1.8
23	Transmitter Implementation Loss (dB)	1.0	1.0	1.0	1.0	1.0
24	Receiver Implementation Loss (dB)	1.2	1.2	1.2	1.2	1.2
25	Required Es/No (dB)	21.8	21.8	21.8	21.8	21.8
26	Required Receiver Sensitivity (dBm)	-102.0	-102.0	-102.0	-102.0	-102.0
27	Es/No Available (dB)	37.3	31.2	28.5	34.3	32.4
28	Residual System Margin (dB)	15.5	9.4	6.7	12.5	10.6

Notes:

1. See Appendix L for detailed discussion of all link budget entries.

2. Operating frequency of 137 MHz.

Table 3-99: Link Margin (Downlink) (dB)

	Range (nmi)				
Altitude (ft)	40	80	110	160	200
5000	14.9	-6.8	*	*	*
18000	15.5	8.6	4.0	-6.5	*
33000	15.5	9.7	6.4	8.5	-1.3
45000	15.5	9.7	6.6	10.7	4.9
70000	15.5	9.7	6.7	12.3	9.4

* Beyond Line of Sight

Note 3: Short term fluctuations in the received signal due to time-varying propagation may lead to additional losses of up to 5 dB. The margins shown in this table predict VDL performance equivalent to that of DSB-AM VHF voice communications.

~~3.9.2 Downlink Power Budget~~

~~Downlink power budgets (shown in Table 3-98) are calculated to determine potential service volume link performance margins. These power budgets are calculated based on the following assumptions:~~

~~- Aircraft transmitter power is 15 watts~~
~~- Aircraft transmitter to antenna cable loss of 3 dB~~
~~- Aircraft antenna gain of -4 dBi (over the angular region of interest)~~
~~- Ground antenna gain of 2.15 dBi (near the horizon)~~
~~- Ground antenna to ground receiver cable loss of 3 dB~~
~~- Loss due to RC transmit filter is 1.8 dB~~
~~- Aircraft transmitter implementation loss allowance is 1.0 dB~~
~~- Ground receiver implementation loss allowance is 1.2 dB~~
~~- Minimum E_b/N_o = 13 dB at 10^{-3} BER~~

~~*Note 1: 3 dB is assumed as a typical aircraft antenna to aircraft receiver cable loss, even though some isolated existing aircraft have backup radio installations with cable losses up to 5.5 dB.*~~

~~Table 3-98 shows downlink power budgets at various free space ranges between the aircraft and LME receiver site. At lower elevations and longer ranges, the total path loss will exceed the free space path loss.~~

~~Table 3-99 data is a combination of the data from Tables 3-95 and 3-98. Table 3-99 therefore indicates the theoretical net link margin expected to be exceeded 95% of the time.~~

~~*Note 2: Uplink (see Section 3.5.2) and downlink power budgets are asymmetrical because the minimum detectable signal is different for ground and airborne receivers. This difference in minimum detectable signal occurs*~~

~~because receiver noise figures, and antennas gains are different between ground and airborne radios. Since external noise is not negligible compared to receiver noise in the 117.975 - 137 MHz band, system noise figure is determined by receiver noise figure, external noise factor, and cable loss, and all these factors can be different between ground and airborne radios.~~

~~Table 3-98: Downlink Power Budget for VHF Digital Radio~~

	~~**Range (nmi)**~~				
	~~**40**~~	~~**80**~~	~~**110**~~	~~**160**~~	~~**200**~~
~~Transmit Power (dBm)~~	~~41.76~~	~~41.76~~	~~41.76~~	~~41.76~~	~~41.76~~
~~Cable Loss – Aircraft (dB)~~	~~-3~~	~~-3~~	~~-3~~	~~-3~~	~~-3~~
~~Antenna Gain – Aircraft (dBi)~~	~~-4~~	~~-4~~	~~-4~~	~~-4~~	~~-4~~
~~Free Space Path Loss (dB)~~	~~-112.57~~	~~-118.59~~	~~-121.36~~	~~-124.61~~	~~-126.55~~
~~Excess Path Loss (dB)~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~
~~Antenna Gain – Ground (dBi)~~	~~2.15~~	~~2.15~~	~~2.15~~	~~2.15~~	~~2.15~~
~~Cable Loss – Ground (dB)~~	~~-3~~	~~-3~~	~~-3~~	~~-3~~	~~-3~~
~~Received Power (dBm)~~	~~-78.66~~	~~-84.68~~	~~-87.45~~	~~-90.70~~	~~-92.64~~
~~Receiver Noise Figure (dB)~~	~~10~~	~~10~~	~~10~~	~~10~~	~~10~~
~~External Noise Figure (dB)~~	~~20~~	~~20~~	~~20~~	~~20~~	~~20~~
~~Effective System Noise Figure (dB)~~	~~17.79~~	~~17.79~~	~~17.79~~	~~17.79~~	~~17.79~~
~~kT_0 (dBm/Hz)~~	~~-174~~	~~-174~~	~~-174~~	~~-174~~	~~-174~~
~~P_r/N_0 (dBHz)~~	~~77.55~~	~~71.53~~	~~68.76~~	~~65.51~~	~~63.57~~
~~Baud Rate (dBHz)~~	~~40.21~~	~~40.21~~	~~40.21~~	~~40.21~~	~~40.21~~
~~E_s/N_0 Before Losses (dB)~~	~~37.34~~	~~31.32~~	~~28.55~~	~~25.30~~	~~23.36~~
~~Transmitter Implementation Loss (dB)~~	~~1.0~~	~~1.0~~	~~1.0~~	~~1.0~~	~~1.0~~
~~Receiver Implementation Loss (dB)~~	~~1.2~~	~~1.2~~	~~1.2~~	~~1.2~~	~~1.2~~
~~Received E_s/N_0 (dB)~~	~~35.14~~	~~29.12~~	~~26.35~~	~~23.10~~	~~21.16~~
~~Received E_b/N_0 (dB)~~	~~30.38~~	~~24.35~~	~~21.58~~	~~18.33~~	~~16.39~~
~~Required E_b/N_0 (Ideal) (dB)~~	~~13~~	~~13~~	~~13~~	~~13~~	~~13~~
~~Required E_b/N_0 (RC Filter) (dB)~~	~~14.80~~	~~14.80~~	~~14.80~~	~~14.80~~	~~14.80~~
~~Margin (dB)~~	~~15.57~~	~~9.55~~	~~6.78~~	~~3.53~~	~~1.59~~

~~Assumptions: Man-Made Noise, 137 MHz, No Excess Path Loss, Effective Noise Figure Referred to Receiver Input Terminals. The entries in Table 3-98 are based on assumptions listed in Section 3.9.2 and are subject to further review and refinement.~~

~~Table 3-99: Link Margin (Downlink) (dB)~~

~~**Altitude (ft)**~~	~~**Range (nmi)**~~				
	~~**40**~~	~~**80**~~	~~**110**~~	~~**160**~~	~~**200**~~
~~5000~~	~~14.97~~	~~-6.65~~	~~*~~	~~*~~	~~*~~
~~18000~~	~~15.57~~	~~8.74~~	~~4.08~~	~~-15.47~~	~~*~~
~~33000~~	~~15.57~~	~~9.54~~	~~6.48~~	~~-0.47~~	~~-10.31~~
~~45000~~	~~15.57~~	~~9.54~~	~~6.68~~	~~1.73~~	~~-4.11~~
~~70000~~	~~15.57~~	~~9.54~~	~~6.78~~	~~3.33~~	~~0.39~~

~~* Beyond Line of Sight~~

~~*Note 3: Service volume regions to the right of the double line in Table 3-99 fall outside of the coverage area of a typical installation for both a 10 watt DSB-AM system and the new 15 watt D8PSK digital system. The current DSB-AM TSO's for airborne transmitters specify either 4 (100 nmi) or 16 (200 nmi) watts. Higher power aircraft transmitters and/or higher gain antennas will increase the downlink link margins and consequently the range.*~~

3.10 Ground Receiver

Only those portions of the ground receiver specification that are different from the airborne receiver (see Section 3.6) are included here; for example: 1) the noise environment is different, particularly with cosited ground radios; and 2) more complex equipment can be utilized in ground receivers. Omitted portions shall be the same as detailed for the airborne receiver.

Section 3.10.1 Minimum Detectable Signal (Downlink)

The minimum detectable VHF radio frequency signal impinging upon a ground antenna which will result in a 10^{-3} BER in the digital transmission shall be 1.21×10^{-12} watts/m^2 in the short range case (or 1.31×10^{-13} watts/m^2 in the long range case), assuming the values listed in Section 3.9.2.

Table 3-100 shows the calculations that establish these minimum detectable signal values.

Note: The downlink calculation in Table 3-100 is based on the (uncorrected) BER of 10^{-3} for both VDL Mode 2 and VDL Mode 3. The ICAO SARPs require a corrected BER of 10^{-4} for VDL Mode 2 data operations. When the effects of the Reed-Solomon encoding/decoding are included to transform the uncorrected BER to the corrected BER, the link margins for VDL Mode 2 operations are reduced by 0.8 dB from those shown in Table 3-98 and Table 3-99. When viewed from a packet-error-rate standpoint under the assumption that a packet contains 248 octets of data, the difference in performance may approach 2 dB, with VDL Mode 3 offering the same performance at lower received power levels. The common standard performance of 10^{-3} (uncorrected) BER has been established to simplify the design and qualification of ground and airborne hardware supporting both VDL Modes 2 and 3. System implementers are cautioned to account for the different performance when establishing coverage areas and operational procedures.

Table 3-100: Minimum Detectable (Downlink) Signal Calculations

	Short Range Case (typically ≤ 110 nmi)	Long Range Case (typically ≥ 160 nmi)	
E_b/N_0 (10^{-3} BER)	13 dB	13 dB	
E_S/E_b	4.77 dB	4.77 dB	
Imp. Loss + RC Loss	4.0 dB	4.0 dB	
E_S/N_0	21.77	21.77	
KT_0	-174 dBm/Hz	-174 dBm/Hz	
Effective Noise Figure	17.79 dB	13.00 dB	
Symbol Rate (R)	40.21 dBHz	40.21 dBHz	
N_0 x R	-116.00 dBm	-120.79 dBm	
Required Receiver Input	-94.23 dBm	-99.02 dBm	
Cable Loss	3.0 dB	2.0 dB	
Antenna Output	-91.23 dBm (7.53x10^{-13} watts)	-97.02 dBm (1.98x10^{-13} watts)	
Antenna Loss	-2.15 dBi	-6.0 dBi	
Antenna Effective Area*	0.63 m^2	1.52 m^2	
Required Power Density	1.21x10^{-12} watts/m^2	1.31x10^{-13} watts/m^2	
Required Field Strength	21 µV/m	7 µV/m	

* Effective Area $= G\left(\lambda^2/4\pi\right)$, with G=(antenna loss)$^{-1}$ and $\lambda = 2.19m$ for 137 MHz.

~~3.10.1 Minimum Detectable Signal (Downlink)~~

~~The minimum detectable VHF radio frequency signal impinging upon a ground antenna which will result in a 10^{-3} BER in the digital transmission shall be 6.88 x 10^{-3} watts/m^2, assuming the values listed in section 3.9.2, and assuming 0.44 m^2 aircraft antenna effective area.~~

~~Table 3-100 shows the calculations that establish this minimum detectable signal value.~~

3.11 Combined Ground Receive/Transmit Characteristics

Only those portions of the combined ground receive/transmit specification that are different from the combined airborne receive/transmit specification (see Section 3.7) are included here; e.g., improved frequency stability, separate transmit and receive antennas, higher gain antennas, and more robust cosited radio performance. Omitted portions shall be the same as detailed for the combined airborne receive/transmit specification.

~~Table 3-100: Minimum Detectable (Downlink) Signal Calculation~~

~~E_b/N_0 (10^{-3} BER)~~	~~13 dB~~
~~E_s/E_b~~	~~4.77 dB~~
~~Imp. Loss + RC Loss~~	~~4.0 dB~~

~~E_s/N_0~~	~~21.77 dB~~
~~kT_0~~	~~-174 dBm/Hz~~
~~Effective Noise Figure~~	~~17.79 dB~~
~~Baud Rate (R)~~	~~40.21 dBHz~~
~~N_0 x R~~	~~-116.00 dBm~~
~~Required Receiver Input~~	~~-94.23 dBm~~
~~Cable Loss~~	~~3.0 dB~~
~~Antenna Loss~~	~~-2.15 dBi~~
~~Antenna Output*~~	~~-93.38 dBm (4.59 x 10^{-13} watts)~~
~~Antenna Effective Area~~	~~0.38 m^2~~
~~Required Power Density~~	~~1.21 x 10^{-12} watts/m^2~~
~~Required Field Strength~~	~~21 µV/m~~

~~*Output of an idealized lossless, isotropic antenna.~~

3.11.1 Frequency Stability

The long-term frequency stability of the carrier shall be ± 0.0002% (± 2 parts per million). This shall be maintained over the operating temperature range and other environmental conditions of ground radios.

3.11.2 Ground Antenna Characteristics

Ground antennas shall be vertically polarized and provide a radiation pattern omnidirectional in azimuth. Ground stations may use the same or different antennas for transmitting and receiving; the gains specified here apply equally to transmitting and receiving. When used for transmitting, a VHF antenna shall be capable of operating at a maximum average input power of 100 watts.

Over the 117.975-137 MHz frequency band, antenna gain near the horizon shall exceed 2.15 dBi. Ground antenna gain so specified does not include the effects of earth reflection, accounted for in the advisory link budgets of Sections 3.5.2 and 3.9.2 which are included in the path loss between the ground and airborne antennas.

Near the zenith, antenna gain shall exceed -12 dBi. Cable loss from the ground antenna to either the VHF radio transmitter or receiver shall not exceed 3 dB.

> Note: *Some ground LMEs may have low-elevation line-of-sight blockage at certain azimuths, due to other antenna towers, buildings, hills, mountains, etc. In such cases, consideration shall be given to employing spatial diversity in the ground network. That is, two or more ground antennas may be provided for a given radio channel, with sufficient physical separation between antennas that their line-of-sight blockages do not occur at the same azimuths. In this case necessary provisions could be made in the ground network to switch between*

the two or more ground antennas so that the antenna producing the stronger signal on uplinks and downlinks shall be selected.

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Appendix A

Membership

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MEMBERSHIP

Special Committee 172

Working Group 2

SIGNAL-IN-SPACE MINIMUM AVIATION SYSTEM PERFORMANCE STANDARDS (MASPS) FOR ADVANCED VHF DIGITAL DATA COMMUNICATIONS INCLUDING COMPATIBILITY WITH DIGITAL VOICE TECHNIQUES

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Appendix B

Tutorial On Aspects of VHF Communications System Design

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B.1.0 Intermodulation

Intermodulation (IM) interference signals are generated when many frequencies are assigned to one ground radio site in the current single-frequency system. IM interference signals are usually generated in the final amplifier of a transmitter and caused by any nonlinear device including the amplifier, loose or corroded joints between two conductors, or in the receiver front end (RF amplifier, mixer or IF amplifier). For example the fundamental frequency of one transmitter can enter a second transmitter through its antenna system and mix with the second harmonic of this transmitter to form a third-order product. The resulting IM product will interfere with a nearby receiver if it is tuned to the frequency. Typical ways to eliminate transmitter IM product interference is through frequency management, transmitter separation, cavity filters and more linear PA designs. However, as the requirement for collocated communications channels increases, the possibility of finding compatible frequency combinations in a single-frequency system decreases. When compatible frequencies cannot be found and large antenna separations cannot be implemented, narrowband mechanically-tuned filters may be required in transmitters and receivers to reduce IM product interference to an acceptable level.

B.2.0 Signal Fading

Variations in received signal amplitude and phase due to reflection, refraction, and shadowing phenomena in the communications channel are termed signal fading. These phenomena can take place in the earth surrounding a ground antenna, in the ground-to-air path through the troposphere, or in the airframe surrounding an airborne antenna. Signal fading will be characterized here by the physical phenomena causing it and their effects upon communication system performance. Slow fading and fast fading are treated separately, since the two types have different operational significance and lead to different remedies.

B.2.1 Physical Mechanisms of Signal Fading at VHF

The principal physical mechanisms causing signal fading on VHF air-ground paths are summarized in Table B-1. Reflection from the surface of the earth is a major cause of signal fading. Specular reflection from a smooth spherical earth is often characterized by a two-ray model (see "Reflection from the Surface of the Earth," CCIR (now ITU-R) Report 1008, Vol. V, 1986). One ray is the direct line-of-sight (LOS) path between transmitter and receiver and the second is the reflection from a point on the earth having equal grazing angles of incidence and reflection. At low elevation angles of the LOS, that is to say at communication ranges approaching the radio horizon, the direct and reflected paths are of nearly equal distance; also, at small grazing angles over smooth terrain or a calm sea, the earth reflection coefficient approaches unity magnitude and 180° phase shift for either vertical or horizontal polarization. Thus, when communicating with aircraft at

Table B-1: Signal Fading On VHF Air/Ground Path

Phenomenon	Effect on Signal	When and Where it Occurs	Magnitude of Fade	Rapidity of Fading	Flat or Frequency Selective	Delay Spread	Spectral (Doppler) Spread	Modulations Affected	Operational Significance	Remedies	Comments
Airborne Antenna Shadowing	Direct LOS signal is lost	In steep banks, at certain angles	Deep	Fairly Slow	Flat	Small	Narrow	All	Limits Range	Message repetition, multiple aircraft antenna	Diffraction at VHF limits fade depth in shadows.
Airframe Reflections and Diffraction	Multipath cancellation	Some reflection or diffraction always occurs	Usually shallow, occasionally deep	Varies from slow to moderately fast	Fairly flat	Small	Narrow to moderately wide	Dense signal constellations with coherent detection	Limits both range and bit rate in a 25 kHz channel	Modulation & coding design, equalization, message repetition	Slowly varying amplitude and phase modulation can be equalized.
Atmospheric Multipath	Multipath cancellation	At low elevation angles	Depth limited at VHF	Slow	Fairly flat	Very small	Narrow	All	Limits range	Link margin	Strong effect at centimeter wavelengths. Much less of a problem at VHF.
Atmospheric Refraction	Variation in signal amplitude	Only near the radio horizon	Deep in some cases	Very slow	Flat	Very small	Very narrow	All	Horizon range varies with time	Monitor atmosphere, link margin	Effect somewhat predictable from weather data.
Earth Reflection: Diffuse	Vary amplitude and phase of resultant	Strongest near airports and urban areas	Shallow	Moderately fast	Frequency selective	Large	Wide	Dense signal constellations with coherent detection	Limits bit rate in a 25 kHz channel	Modulation & coding design, equalization, message repetition	As long as an LOS exists, magnitude of fade due to diffuse multipath is small.
Earth Reflection: Specular	Multipath cancellation	Over smooth earth at low grazing angles	Deep	Very slow	Flat	Very small	Very narrow	All	Limits range	Link margin	Fade depth is strongly dependent upon terrain.
Foliage Attenuation	Direct LOS signal is attenuated	At low elevation angles at some sites at some azimuths	Variable, sometimes deep	Very slow	Fairly flat	Very small	Very narrow	All	Limits range	Higher ground antenna, link margin	Spatial diversity (multiple ground sites) also useful.
Rotorcraft Blade Reflections	Vary amplitude and phase of resultant	All the time	Shallow	Very fast	Fairly flat	Small	Very wide	Dense signal constellations with coherent detection	Limits bit rate in a 25 kHz channel	Modulation and coding design	Difficult problem. May need special waveform for rotorcraft

ranges within the radio horizon over a smooth earth, the direct and reflected rays can nearly cancel each other and deep signal fades of 10-20 dB can often be observed. Such fades vary slowly with time and are not very frequency selective over the 117.975-137 MHz band. Because the direct and reflected paths are close to each other at low elevation angles, both delay and Doppler spread of the composite received signal are very small.

A criterion sometimes specified for design of LOS radio links is to obtain first Fresnel zone clearance; i.e., to let no point on the earth's surface lie within the first Fresnel zone around the LOS between transmitter and receiver. The first Fresnel zone is defined as the locus of all points where the total path length between transmitter and receiver is up to one-half wavelength greater than the distance along the direct path. Generally, when first Fresnel zone clearance is obtained, earth reflections do not increase path loss much beyond the free space path loss for the same distance. The trouble with using this criterion for air-ground links in the 117.975-137 MHz frequency band is the fact that first Fresnel zone clearance cannot be obtained at low elevation angles (long ranges) with practical ground antenna heights. As a result, a long-range communication link design must take into account fading due to reflection from the earth's surface.

Diffuse reflection from the surface of the earth also causes signal fading. This phenomenon can be particularly strong in urban areas, where vertical buildings provide significant reflections over a range of azimuth and elevation angles. Because diffuse reflections add noncoherently (with random phase) at the communications receiver, as contrasted to the coherent (in-phase) addition of specular reflections, the total amplitude of diffusely reflected signals is almost always smaller than the amplitude of the direct LOS signal. Thus, the effect of diffuse reflection is to cause fluctuations in the amplitude and phase of the resultant received signal, but seldom to cancel the direct LOS signal and produce a deep fade. Fade depth is usually less than 10 dB. Because reflected signal path lengths can be many wavelengths longer than that of the direct LOS signal, the amplitude and phase of the reflected signal both change as an aircraft moves along its flight path. This causes moderately fast frequency selective fading due to diffuse reflection from the earth's surface, with approximate worst-case delay spreads up to 200 microseconds and approximate worst-case Doppler spreads up to 100 Hz.

At some ground sites, foliage attenuation of the VHF radio signal may occur at low elevation angles. Attenuation of the direct LOS signal, which can cause either shallow or deep fades, depends upon the path length through the foliage. Unlike microwave frequencies, radio waves in the 117.975-137 MHz band penetrate foliage to some extent. Fading due to foliage attenuation varies slowly with time, is fairly flat across the 117.975-137 MHz frequency band, and has very small delay and Doppler spreads.

Variations in the decrease in index of refraction with height in the troposphere as weather changes cause variations in atmospheric refraction (ray bending). Thus, an aircraft which is just within the radio horizon for a given degree of downward ray bending may be over the horizon for a slightly lesser degree of downward ray bending, leading to a deep slow fade when the weather changes. Such fades are flat across the 117.975-137 MHz band and have very little delay or Doppler spread. For air-ground paths entirely within the troposphere, one can interpret changes in atmospheric refraction as changes in the ratio K of effective earth radius to true earth radius from its nominal value of 4/3. In the United States, a typical variation in K is from 1.1 to 1.5. For an aircraft at 30,000 ft, for example, the distance to the radio horizon from a ground antenna at 100 ft height changes from 204.5 nmi at K=1.1 to 238.8 nmi at K=1.5.

A closely related cause of signal fading is atmospheric multipath - interference between multiple ray paths through the troposphere - caused by local variations in index of refraction. Atmospheric multipath can cause deep fading, up to 30 dB, on microwave radio relay links. On VHF air-ground paths, its effect is much smaller for two reasons: (1) the much longer wavelength, which requires much larger refractive index variations to produce multipath cancellation, and (2) the non-zero elevation angle of air-ground paths, which causes air-ground paths not to be parallel to atmospheric layers.

Obstruction of the radio LOS on an air-ground link by shadowing of the airborne antenna can cause deep fades at all frequencies in the 117.975-137 MHz band. Shadowing by a wing can occur when an aircraft banks; the engines and tail of an aircraft can also shadow an airborne antenna at certain angles. Because of the long wavelengths to be used by the VHF data radio (2.2 m at 137 MHz) diffraction around obstacles will limit fade depth in shadows, but fade depth can still be 10-20 dB. Fades due to antenna shadowing are fairly slow, with a small delay spread and a fairly narrow Doppler spread, the latter being proportional to turn rate.

Reflections and diffraction from the airframe occur, even when an airborne antenna has an unobstructed LOS. Most of the time reflections cause small variations in signal amplitude and phase, but at some angles strong specular reflections can occur and cause multipath cancellation to take place, resulting in a deep fade.

In straight line flight the radio LOS angle relative to an aircraft rotates slowly, resulting in slow fading with a fairly small delay spread (less than or equal to the transit time across the aircraft dimensions) and a narrow Doppler spread. Aircraft turns cause faster fading, increasing the Doppler spread but not the delay spread.

Reflections from the blades of rotorcraft are a special case because they rotate so fast. As a result, the blade reflections have a very wide Doppler spread, up to 500 Hz in the worst case of path geometry and blade tip velocity, resulting in very fast fading. The delay spread is, however, no greater than for fixed-wing aircraft of comparable size. Blade rotation also produces strong periodic components in the frequency spectrum of the reflected signal. On the other hand, because total blade area is limited, the magnitude of the reflected signal is significantly less than that of the direct LOS signal. Thus, most of the time fading is shallow rather than deep, so that its effect is to rapidly vary the amplitude and phase of the resultant signal, but seldom to cause it to fade below the receiver noise level.

As shown in Table B1, a number of physical phenomena lead to slow fading of the VHF air-ground communications signal: specular reflection from the earth's surface, foliage attenuation, atmospheric refraction, atmospheric multipath, and most cases of airborne antenna shadowing. Signal fades due to these phenomena extend across the 117.975-137

MHz frequency band. The delay spreads are much smaller than the symbol duration of 95.2 microseconds, so that the principal effect of slow fading is a reduction in signal amplitude, rather than intersymbol interference. Doppler spreads are narrow, less than one Hertz in most cases, so that coherent detection is feasible; i.e., the received signal Doppler spread is less than the bandwidth of a typical phase tracking loop. These slow fading mechanisms affect all types of signal modulation and limit maximum communication range. The most generally useful remedy for slow fading is to provide a link margin of 10-20 dB over free-space propagation conditions to cover slow fading. In some cases, higher ground antennas or spatial diversity - multiple ground stations within LOS of an aircraft - can reduce the required link margin. If airborne antenna shadowing does not last too long, message repetition in an ARQ protocol can also restore the communication link.

The physical phenomena producing fast fading tend to limit the usable data rate in a 25 kHz channel. Diffuse earth reflection in urban areas can have a delay spread which is a significant fraction of the 95.2 microseconds symbol duration, leading to intersymbol interference. It is the only fading mechanism which can do this - all the rest have too small a delay spread. Diffuse earth reflection can also have a wide Doppler spread as an aircraft flies through minima and maxima of the interference patterns produced by multiple earth reflections. The effect of diffuse earth reflection upon the radio channel is to produce a reflected signal component with fluctuating amplitude and phase that adds to the relatively steady LOS signal component. The reflected signal component is seldom large enough to produce deep fades, but it does produce moderately fast fluctuations in both amplitude and phase of the composite received signal. These fluctuations can cause symbol errors (if unequalized) whenever their magnitude exceeds the separation of points in the D8PSK signal constellation. The key technical issue with diffuse earth reflection is the need to characterize amplitude and phase fluctuations of the composite received signal and to analyze their effect upon each signal constellation, phase tracking loop, and equalization algorithm to be employed, determining the resulting symbol error rate. Then the adequacy of the forward error correction and message repetition procedures to be used can be determined. In this way, the largest feasible size of the signal constellation and the maximum feasible bit rate in a 25 kHz channel can be found for a specified link reliability.

Airframe reflections produce moderately fast fading. Because of finite aircraft size, multipath delay spread due to airframe reflections, unlike diffuse earth reflections, is too small to cause intersymbol interference. Airframe reflections can, however, produce fluctuations in the amplitude and phase of the composite received signal that affect the performance of signal demodulation, particularly when dense signal constellations are coherently detected. The same analyses of phase tracking loops and equalization algorithms recommended for diffuse earth reflection fading need to be done for signal fading caused by airframe reflections. One might note that whereas the Doppler spread of diffuse earth reflection is proportional to aircraft speed, the Doppler spread of airframe reflections is proportional to the LOS rotation rate and to aircraft turn rates. Amplitude fluctuations caused by both antenna shadowing and airframe reflections can be determined from measured VHF aircraft antenna patterns and from typical roll, pitch and yaw rates. The phase of far-field antenna patterns is not usually measured, however. Phase fluctuations of the composite received signal due to airframe reflections could be determined by analysis using electromagnetic scattering computer programs (see "Antennas on Aircraft, Ships, or Any Large, Complex Environment," W. D. Burnside and R. J. Marhefka, Chapter 20 in "Antenna Handbook" by Y. T. Lo and S. W. Lee, Van Nostrand Reinhold, New York, 1988).

Rotorcraft blade reflections differ from the other causes of signal fading summarized in Table B-1 by their very wide Doppler spread, caused by the simultaneous scattering of the VHF radio signal from blades approaching and receding from a ground station. The wide Doppler spread and strong periodic components in the spectrum of the blade reflections causes the amplitude and phase of the composite received signal to fluctuate rapidly and periodically, perhaps too rapidly to be equalized with the proposed equalization algorithms. In addition, phase tracking of the composite received signal to provide a phase reference for coherent detection may be difficult. Widening the tracking loop bandwidth to accommodate signal Doppler spread reduces signal-to-noise ratio in the loop and produces phase noise on the reference signal input to the synchronous demodulator. These problems require detailed analysis. Possible remedies include: (1) A special waveform for VHF radio links to and from rotorcraft, using a signal constellation with widely separated points, and (2) a stronger, lower rate, error correcting code for rotorcraft radios which can tolerate a higher input channel symbol error rate. Either of these remedies will reduce the available information bit rate in a 25 kHz channel.

B.3.0 System Delay Components

B.3.1 VDL Mode 2 Message Delay

The system VDL Mode 2 transfer delay is defined between reference points B and C of Figure 1-1. The five components comprising the system delay are listed in the following table with values expressed at the 95% point of their distributions. As this data shows, the only significant component is the access delay.

Delay Component		Value (95%)
D_S	Receive/Transmit turnaround[1]	1 ms
D_T	Packet transmission time[2]	250 ms
D_R	Propagation (range) delay[3]	1.3 ms
D_P	Processing delays[4]	100 ms
D_A	Access delays[5]	3000 ms

Notes:

1. D_S *is specified in Section 3.2.1.9.*
2. D_T *is determined by the ratio of the packet length (bits) and the channel information rate (bits/sec).*
3. D_R *is expressed herein for a range of 200 nmi between transmitting and receiving stations.*
4. D_P *includes estimates for delays due to the relevant processing functions listed in Section 3.0 and for the additional interfacing protocols included between the reference points.*
5. D_A *includes the effects of packet collisions in the transmission channel.*

B.3.2 VDL Mode 3 Message Delay

The system VDL Mode 3 transfer delay is defined separately for voice and data.

B.3.2.1 VDL Mode 3 Voice Message Delay

For VDL Mode 3 voice services, the transfer delay is defined between points B and C of Figure 1-2. The components of delay are listed below assuming no circuit setup time is required (dedicated ATC voice circuits) and that there is no contention for access to the voice circuit. From these delay components the overall system VDL Mode 3 transfer delay can be taken as 200 ms for voice worst case.

Delay component	Value (worst case)
Vocoder sampling	20 ms
Vocoder analysis	40 ms
TDMA framing and transmission	105 ms
Vocoder synthesis	20 ms
Other processing delays	15 ms

B.3.2.2 VDL Mode 3 Data Link Message Delay

For VDL Mode 3 data services, the transfer delay is defined between points B and C of Figure 1-1. The traffic model and delay profiles are listed below.

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Delay Component		Downlink Value (95%)	Uplink Value (95%)
D_Q	Queuing delay[1] (less than 80% utilization)	3,528 ms	528 ms
D_P	Processing delay[2]	10 ms	10 ms
D_A	Access delay[3]	1,500 ms	0 ms
D_S	Receive/Transmit turnaround[4]	2 ms	2 ms
D_T	Packet transmission time[5] (576 bit/packet)	250 ms	250 ms
D_R	Propagation delay[6]	2 ms	2 ms

Notes:

1. *D_Q (packet waiting to be processed) is a function of packet interarrival rate and the sum of remaining timing components listed below.*
2. *D_P includes estimates for delays due to the relevant processing functions listed in Section 3.0 item (c), and for additional interfacing protocol included between the reference points.*
3. *D_A includes the effects of packet collisions in the transmission channel.*
4. *D_S is as specified in Section 3.3.1.6.*
5. *D_T is time determined by the ratio of packet length (bits) and the time channel rate (bits/sec).*

~~6.~~6. *D_R is the time for the RF signal to cover a range of 200 nmi between transmitting and receiving stations.*

B.3.2.2.1 Traffic Model

The Aeronautical Mobile Communications Panel (AMCP) Working Group D (WG-D) and RTCA SC-172 have adopted a terminal domain application traffic model for simulation efforts as summarized in Table B-2. High priority corresponds with Urgent/Flight Safety priority, per Table 3-63. Medium priority corresponds with Meteorological and Flight Regularity priority and Low priority corresponds with Aeronautical Information priority. This traffic model includes four applications, whose characteristics are described by message size, message rate, arrival pattern, and priority. These traffic characteristics are assumed to be equal for all aircraft. Note that the combined uplink and downlink Air/Ground data link traffic in Table B-2 is used as a reference "Load Factor" of 1.0. The load factor and number of aircraft served per channel (or per user group) are the parameters that are varied to assess capacity. The total loading of the air/ground communications link therefore depends on the number of aircraft as well as the load factor. Each load factor defines one set of packet arrival rates. The simulation model is then run for different combinations of number of aircraft and Load Factor. The range of Load Factors used for the two models is somewhat different: 0.2 to 8.0 (including 1.0) for the subnetwork model; and 1.0 and 2.0 for the integrated model.

Table B-2: Terminal Domain Application Message Traffic Model

Message Distribution	Priority (Note 7)	Uplink		Downlink	
		average message rate in steady state	average size in bits	average message rate in steady state	average size in bits
Exponential inter-arrival with Poisson message size	High	0.017	137	0.024	110
	Medium	0.0017	198	0.0008	100
	Low	0.001	2400	0.002	2400
Constant (Notes 4 & 5)	Low	0.017	3325	0.0033	1760

Notes: 1. Rates are in number of messages per second per aircraft
2. Each message is acknowledged at Data Link Sublayer except broadcast
3. Ack of uplink message uses downlink M Subchannels; ack of downlink message requires 4 octets conveyed in the V/D (data) subchannels
4. Broadcast service provided for constant uplink messages
5. Periodic fixed size downlink meteorological observations
6. All traffic collectively represents a Load Factor of 1
7. Each priority has its own COTP connection

B.3.2.2.2 Subnetwork (Data Link) Model Performance

Measures of performance for the data link service include channel throughput and message delays. Channel throughput is determined by system configuration, number of active aircraft served by the channel, and message traffic intensity (i.e., Load Factor). Message delay is determined by system configuration, channel throughput, and message priority. Channel throughput, subnetwork message delays, and channel resource utilization of each system configuration and data traffic scenario can be determined by simulation.

Maximum channel throughput theoretically possible (i.e., upper bound) for a given system configuration may not be achievable in practice. Other constraints, such as the subnetwork 95th percentile delay requirement, further reduce the achievable channel throughput. With prioritized data link service, it is possible to meet specific message delay requirements (for urgent/flight safety priority messages in Table 3-63) while maintaining a relatively high level of channel throughput.

Subnetwork message delay performance, for the urgent/flight safety priority messages, that meets the delay requirements is summarized in Table B-3 (for 2V2D and 3T system configurations). The maximum sustainable channel throughput ranges from 7 kbps to 10.2 kbps. Subnetwork delay values apparently meet the message delay requirements (i.e., 5 seconds and 3 seconds for 95th percentile and mean, respectively) at average channel throughput of 2.5 kbps with 80 aircraft per channel (or 40 aircraft per user group) and a Load Factor of 1 for the 2V2D configuration, and at average channel throughput of 4.5 kbps with 80 to 160 aircraft per channel and a Load Factor of 2 or less for the 3T configuration. The subnetwork delay values are achieved by using fine-tuned DLS and MAC service system parameters.

Table B-3: VDL Mode 3 Data Link Message Delay Performance for Frame-based SNDCF

Channel Configuration	Absolute Upper bound Capacity	Maximum Channel Throughput Achieved By Simulation	Effective Channel Throughput with Delay Constraints	Subnetwork Delay				number of aircraft per 25 kHz channel and Load Factor
				uplink		downlink		
				mean	95th	mean	95th	
2V2D	8.2 kbps	7 kbps	2.5 kbps	0.52	1.5	1.0	3.5	80 aircraft with Load Factor of 1
3T	12.4 kbps	10.2 kbps	4.5 kbps	0.23	0.48	0.75	2.8	80 aircraft with Load Factor of 2 or 160 aircraft with Load Factor of 1

Note: Subnetwork Message Delays are in seconds (Urgent/Flight Safety priority message only)

B.4.0 Message Integrity

Digital data transmission systems must guarantee a very low residual error rate. This means that there are no errors in the delivered packets, packets are not lost, packets are not delivered out of order, and packets are not duplicated. This can be accomplished in a number of ways, by adding redundancy which can be resolved to reduce the raw error rate available on the channel. This redundancy can be in space (e.g., multiple antennas), frequency (e.g., repeating on different channels), or time (e.g., error detecting and error correcting coding).

Real-time digital voice transmission systems must guarantee a reasonable residual error rate, but it is more important that the delay be within very strict limits. In fact, most codecs can tolerate a bit error rate (BER) of 10^{-3} and occasional lost voice frames. Consequently, time redundancy must be carefully designed to not violate these critical constraints.

Both space and frequency redundancy (better known as diversity) attempt to overcome a bad radio frequency (RF) channel by providing alternate channels. Because two antennas spaced ten wavelengths apart tend to receive statistically independent signals, the probability of a fadeout is drastically reduced. However, this scheme cannot resolve signals because of low received signal level or a nearby noise source. Frequency diversity can correct both fading channels and local narrowband noise sources, but require the use of another frequency to do so.

The most common method of combating noise problems is time diversity. These methods fall into two orthogonal classes: error correcting and error detecting with repeat. Simply put, one method transmits additional data in a single transmission so that errors can be corrected, and the other method transmits additional data so that the original message can be retransmitted (and hopefully will not collide with the noise sources again). The former algorithm is called Forward Error Correction (FEC), and the latter is called Automatic Repeat Request (ARQ). However, ARQ techniques are not used in real-time digital voice applications because of the excessive time delays -- if the voice frame does not arrive, it is lost.

Of course, there is the final level of time diversity -- the human. If the end user detects a problem, he will reinitiate the exchange (e.g., requesting the speaker repeat something, or perhaps restarting a database transfer).

B.4.1 Forward Error Correction

There are two types of error correction codes: trellis coding and block coding. Trellis coding combines the coding scheme with the modulation scheme, and uses restricted choice as the method of coding. That is, the transmitter maintains a state. Based on the incoming data stream and the current state, the transmitter transits to a new state and emits a data code, which is chosen from a subset of the entire alphabet. Thus, the receiver can attempt to decode the received signal, determine what states the transmitter has transited through in order to have been able to transmit that sequence of data symbols, and thus determine the original bit stream. The most typical algorithm for this decoding process is called the Viterbi algorithm, which is an optimal Maximum Likelihood Estimator (MLE) process.

The other type of error correction coding is called block coding. In a block code, the transmitter computes a new bit stream from the input bit stream (in a systematic block code, this is done by appending check words to the original bit stream). After decoding the bit stream, the receiver performs a mathematical procedure to determine the most likely transmitted message. Not surprisingly, the complexity of this procedure is proportional to the power of the code. Some of the more powerful block codes are the Bose-Chaudhuri-Hocquenghem (BCH) and Reed-Solomon (RS) codes.

B.4.1.1 Trellis Codes

Trellis codes can be linear functions or nonlinear functions; in the former case, these codes are also known as convolutional codes. These trellises are easier to analyze (because the error syndromes are independent of the input data sequence), but linear trellises can only achieve 180^o rotational invariance; whereas nonlinear trellises can achieve 90^o rotational invariance. This means that the receiver can lock up either 90^o, 180^o, or 270^o out of phase with the transmitter and the recovered data stream will still be correct.

Because a few errors in quick succession can easily cause the decoder to output an error sequence, trellis codes are particularly sensitive to burst errors. Consequently, a procedure called interleaving is performed to attempt to isolate the bit errors from each other. Since the effectiveness of this procedure is directly related to the additional delay it causes, interleaving is not a perfect solution for burst errors.

B.4.1.2 Linear Block Codes

An (n, k) linear block code maps a k-bit message into an n-bit encoded sequence (n, k). The map of a systematic block code ensures that part of the sequence (traditionally the beginning) is the k-bit message, with the remaining n-k digits being check digits. Any block code can be used as an error detection or error correction code, although a code can detect approximately twice as many errors as it can correct. A typical method to significantly increase the efficacy of error correcting codes is for the demodulator to output the confidence with which it determined each bit. This so-called soft decoding typically provides a 2-3 dB advantage over hard decoding, because it is easier for the decoder to determine which bit is in error.

The first block codes used were simple codes such as 7-bit odd parity, Longitudinal Redundancy Check (LRC), and Hamming codes. However, there is another class of codes called cyclic codes which are both powerful and easy to implement in hardware with feedback shift registers. The most powerful of the cyclic codes are the BCH codes which are the most powerful codes for small block lengths (less than a few hundred bits).

One of the most popular subclasses of the BCH codes (which happened to be discovered prior to the BCH codes) is the class of nonbinary RS codes. Reed-Solomon codes have the enviable property that, for a given n and k, they achieve the largest possible code minimum distance. This is possible because the k-bit message stream is broken up into k1 words of m bits each ($m\ k_1 = k$), thus dramatically increasing the number of possible codewords without increasing the possible number of message sequences. Because a t-correcting code can correct up to t words, irrespective of the words' locations and the number of bits in error in each word, RS codes are especially good at burst error correction. However, the decoding must now be done in a Galois Field of size 2^m.

This math is exceedingly complex -- the continuous increases in central processing unit (CPU) power directly affect the ability to implement the higher order codes -- and the algorithms to use soft decision decoding for RS codes are only now appearing in the literature.

Reed-Solomon codes were selected for use in VDL Mode 2 because they are better than trellis codes at handling burst errors. The RS (255, 249) code requires a bandwidth expansion of less than 3%. Although a rate 3/4 trellis code is able to operate at a somewhat higher channel BER, i.e., about 10^{-2} instead of 3.5×10^{-3}, its bandwidth expansion is 25%.

B.4.2 Automatic Repeat Request (ARQ)

The most frequently used method of diversity is a time diversity method called ARQ. The sender transmits a numbered frame to the receiver, along with an error detecting (ED) code. If it was received successfully (the ED code is valid), then an acknowledgment (ACK) is transmitted from the receiver to the transmitter; otherwise, a negative acknowledgment (NAK) is returned. If the transmitter receives a NAK, it will retransmit the frame. If the transmitter does not receive either response (either because the receiver did not even detect enough of the frame to determine the need to NAK the transmitter or because the ACK (or NAK) itself was not received correctly), then it will timeout and retransmit the frame again. Because the frame is numbered, the receiver can determine if the frame has been received already and can discard it. If the receiver has traffic for the transmitter, then it can typically piggyback the ACK on the reverse-bound traffic. There are four basic variations of ARQ, which trade off implementation (and required memory resources) for throughput efficiency.

It is critical in these schemes that both stations have a correct understanding of the other station's state. Hardware failures, software bugs, as well as error detection failures can sometimes cause the protocol to get confused. When this occurs, the stations will reset the protocol and will potentially lose traffic. It is the responsibility of the next layer up to resolve these failures. The most typically used error detection code at the link layer is a shortened Hamming code called a Cyclic Redundancy Check (CRC). Selecting the size of the CRC is a tradeoff of the ED failure rate versus the wasted bandwidth versus the maximum size message to be protected. Selecting an optimal CRC of a given size requires knowing the maximum size message to be protected. (See G. Castagnoli, J. Ganz, and P. Graber, "Optimum Cyclic Redundancy-Check Codes with 16-Bit Redundancy," IEEE Trans. Commun., Vol. COM-38, pp. 111-114, January 1990.) The most common forms of CRC generators available in hardware are CRC-16 and CRC-CCITT, which can reliably protect messages up to 32,768 bits in length.

The CRC is a very effective code that is easy to compute in hardware, but expensive to compute in software. Consequently, protocol layers which do not interface directly with hardware (such as the network or transport layer) use a checksum called Fletcher's algorithm which is nearly as effective as a CRC, but is far easier to compute in software.

B.4.2.1 Stop-and-Wait ARQ

The simplest form of ARQ is called stop-and-wait ARQ. In this version, the transmitter cannot transmit frame N until frame N-1 is acknowledged; hence, the transmitter must stop and wait for an acknowledgment. The primary disadvantage with this scheme is that the transmitter must relinquish the channel after every transmission, and an acknowledgment is required for every frame. If the propagation delay of the channel is large, then the amount of time spent waiting for an acknowledgment can consume a significant percentage of the available bandwidth. Note that the frame only needs a single bit to differentiate the current frame from the new frame.

B.4.2.2 Go-Back-N ARQ

The next major enhancement to ARQ protocols is called Go-Back-N ARQ. In this scheme, the transmitter numbers the frames to be sent from 0 to M-1 (or modulo M), and can transmit up to M-1 frames before needing to stop and wait for an ACK. The receiver will only accept frames in order, requesting that the transmitter go back and retransmit everything after the bad frame. For example, if frames 0, 1, 2, and 3 are sent by the transmitter and the receiver detects an error in frame 2, then it will request retransmission of frame 2, implicitly acknowledging frames 0 and 1.

Note that whether frame 3 was received correctly is irrelevant, the receiver will not process frame 3 until frame 2 has been received correctly. This scheme has several advantages over stop-and-wait ARQ (which can be seen to be a simplification of go-back-N with M = 2). Primarily, multiple frames can be sent in a single transmission, thus reducing the number of times the channel needs to be accessed. Also, the number of acknowledgments required drops dramatically, because a single ACK can now acknowledge multiple frames. However, the receiver is still occasionally discarding frames which were received successfully, in order to reduce complexity.

B.4.2.3 Modified Go-Back-N ARQ

Many attempts have been made to improve the performance of go-back-N ARQ in order to avoid having to use selective reject ARQ (see Section B4.2.4 below). Variations on the standard go-back-N ARQ include having the transmitter send multiple copies of the frame during retransmissions, or having the receiver store the bad frames and attempt to assemble a good frame, e.g., if only a few bits are in error in each frame, then it should be possible to cut-and-paste together a good frame with clever post-processing. Many of these schemes approach the efficiency of canonical selective reject ARQ (although they can also be used to improve selective reject ARQ).

B.4.2.4 Selective Reject ARQ

Selective reject ARQ is the last of the three canonical ARQ algorithms. In this scheme, the receiver accepts all good frames, and rejects only those frames which were received in error. This prevents the need to resend a frame which has been successfully received earlier. However, if the number of errors is small, then the penalty for retransmitting is also small, and so the advantage of selective reject ARQ is negated by the need to have complex buffer management and resequencing algorithms. Another disadvantage of selective reject ARQ is that the number of outstanding frames is only M/2 frames (instead of M - 1 frames). It is very unusual to use selective reject ARQ unless both the number of discarded good frames and the likelihood of discarding frames are large.

B.4.2.5 Hybrid ARQ

From B. Sklar, Digital Communications: Fundamentals and Applications, 1988, p. 260:

The major advantage of ARQ over FEC is that error detection requires much simpler decoding equipment and much less redundancy than does error correction. Also, ARQ is adaptive in the sense that information is retransmitted only when errors occur. On the other hand, FEC may be desirable in place of, or in addition to, error detection, for any of the following reasons:

1. A reverse channel is not available or the delay with ARQ would be excessive;

2. The retransmission strategy is not conveniently implemented; or

3. The expected number of errors, without corrections, would require excessive retransmissions.

Since ARQ and FEC are orthogonal, the design decisions are independent. Therefore, a data system can use both trellis coding as well as go-back-N ARQ to ensure that frames are received correctly and have a high overall reliability. However, a real-time digital voice system typically only uses trellis or block coding to ensure that most frames have a sufficient reliability without incurring the long time penalty of ARQ. Further, the coding gain provided by FEC allows the designer to use a smaller transmitter.

B.4.3 Interleaving

Burst errors are caused by signal fading due to multipath transmission, impulsive noise, and channel crosstalk, deliberate jamming (partial-band jamming, for example), etc. To counter burst errors, an interleaver can be placed between the encoder and modulator in both digital voice and data, so that the symbols are interleaved before transmission. Interleaving significantly improves the performance of decoder error correction in digital data transmission.

B.4.3.1 Block Interleaving

A block interleaver uses two R-row by C-column random access memories. The transmitter reads encoder output symbols into a memory by columns (or rows) until it is full. Then the memory is read out by rows (or columns) and sent to the encoder. While one memory is filling, the other is being emptied. The size of each cell in the table is determined by the system design. For instance, the cell size for trellis codes would be a single bit while the cell size for block codes would be the size of a code word.

B.4.3.2 Convolutional Interleaving

The convolutional interleaver can be implemented by shift registers with increasing lengths. In a convolutional interleaver, the code symbols are shifted sequentially into a bank of registers with increasing lengths. With each new code symbol, the commutator (multiplexer) switches to a new register, and the new code symbol is shifted in while the oldest code symbol in that register is shifted out to the channel. The input and output commutators (multiplexers) operate synchronously.

A convolutional interleaver typically saves approximately one-half the interleaver delay incurred compared to a block interleaver.

Appendix C

Acronyms

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Acronyms

AAC	Aeronautical Administrative Communication
ABM	Asynchronous Balanced Mode
A/C	Aircraft
ACARS	Aircraft Communications Addressing & Reporting Systems
ACK	Acknowledgement
A-CLDL	Acknowledged-Connectionless Data Link
ADCE	Aircraft DCE
ADLP	Aircraft Data Link Processor
ADM	Asynchronous Disconnected Mode
A/G	Air/Ground
AGC	Automatic Gain Control
ALT	Alternate Timing Source(s)
AMBE	Advanced Multi-Band Excitation
AMCP	Aeronautical Mobile Communications Panel
AM(R)S	Aeronautical Mobile (Route) Service
AMS(R)S	Aeronautical Mobile Satellite (Route) Service
ANI	Aircraft Network Interface
AOC	Aeronautical Operational Control
APC	Aeronautical Public Correspondence
ARQ	Automatic Repeat Request
ARS	Administration Region Selector
ASOS	Automated Surface Observing System
ATC	Air Traffic Control

ATIS	Automatic Terminal Information System
ATM	Air Traffic Manager
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Service
AVLC	Aviation VHF Link Control
AWGN	Additive White Gaussian Noise
AWOS	Automated Weather Observing System
BCD	Binary Coded Decimal
BCH	Bose-Chaudhuri-Hocquenghem
BER	Bit Error Rate
BFR	Block Failure Rate
bps	Bits Per Second
CAA	Civil Aviation Authority
CCIR	International Radio Consultative Committee (now ITU-R)
CCITT	International Telegraph & Telephone Consultative Committee (now ITU-T)
CDMA	Code Division Multiple Access
CLNP	Connectionless Network Protocol
CMD	Command (frame)
CPU	Central Processing Unit
C/R	Command/Response (bit)
CRC	Cyclic Redundancy Check
CSC	Common Signaling Channel
CSMA	Carrier Sense Multiple Access
CTC	Coast Timing Counter
CTS	Cleared To Send

CW	Continuous Wave
D	Data
D8PSK	Differential Eight Phase Shift Keyed
dB	Decibel
dBc	Decibels Relative to the Carrier Power Level
dBi	Decibels Relative to an Isotropic Antenna
D-bit	ISO 8208 Delivery bit
dBm	decibels relative to 1 milliwatt
DCE	Data Circuit-terminating Equipment
DFDAU	Digital Flight Data Acquisition Unit
DISC	Disconnect (Frame)
DLE	Data Link Entity
DLS	Data Link Service
DLSAP	Data Link Service Access Point
DLSP	Data Link Service Provider
DM	Disconnected Mode (Frame)
DOC	Designated Operational Coverage
DSB-AM	Double-Sideband Amplitude Modulation
DTE	Data Terminal Equipment
DTR	Data Transfer Ready
DUI	Data Unit Identifier
DXE	denotes either: Data Terminal Equipment or Data Circuit-Terminating Equipment
ED	Error Detecting
EOM	End Of Message

ES	End System
EVM	Error Vector Magnitude
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FCS	Frame Check Sequence
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FIS	Flight Information Services
FIS-B	Flight Information Services-Broadcast
FRM	Frame Reject Mode
FRMR	Frame Reject (Frame)
GF	Galois Field
GNI	Ground Network Interface
GNI_p	GNI Primary
GPS	Global Positioning System
GSC	Ground Station Code
GSIF	Ground Station Information Frames
H	Handoff Check Message
HDLC	High Level Data Link Control
HEX	Hexadecimal
HO	Handoff
HSNR	Highest Sequence Number Received
HTC	Highest Two-Way Channel
IA5	International Alphabet No. 5, the character set defined in ISO 646 table 5
IATA	International Air Transport Association

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ICAO	International Civil Aviation Organization
ID	Identification (Identifier)
IDRP	Inter-Domain Routing Protocol
IM	Intermodulation
INFO	Information (Frame)
INIT	Initialization
IS	Intermediate System
ISH	Intermediate System Hello (packet)
ISO	International Organization for Standardization
ITU-R	International Telecommunication Union - Radiocommunication Sector
ITU-T	International Telecommunication Union – Telecommunications Sector
IW	Internetworking
LBAC	Logical Burst Access Channel
LCI	Logical Channel Identifier
LCN	Logical Channel Number
LCR	Link Connection Refused
LME	Link Management Entity
LN	Local Negotiation
LOS	Line of Sight
LRC	Longitudinal Redundancy Check
LSB	Least Significant Bit
LSO	Least Significant Octet
LTC	Lowest Two-Way Channel
LWS	Local Wait State
M	Management

MAC	Media Access Control
MASPS	Minimum Aviation System Performance Standards
MbB	Make-before-Break
M/I	Maintained/Initialized Status Bit
MIB	Management Information Base
MID	Message Identification
MLE	Maximum Likelihood Estimator
MOPS	Minimum Operational Performance Standards
ms	Milliseconds
MSB	Most Significant Bit
MSK	Minimum Shift Keying
MSL	Mean Sea Level
MSO	Most Significant Octet
MU	Management Unit
NAK	Negative Acknowledgement
NAS	National Airspace System
NESN	Next Expected Sequence Number
NET	Network Entity Title
nmi	Nautical Miles
NPDU	Network Protocol Data Unit
NSAP	Network Service Access Point
OAT	Optional Auxiliary Terminal
OCP	Outgoing Connection Pending
OOOI	Out-Off-On-In
OSI	Open Systems Interconnection

PDU	Protocol Data Unit
PECT	Peer Entity Contact Table
P/F	Poll/Final (bit)
PH_SDU	Physical Service Data Unit-The unit of service data as defined in ISO 7498, paragraph 5.6 for the Physical Layer
PI	Parameter Identifier
PLP	Packet Layer Protocol
PN	Pseudo Noise
ppm	Parts Per Million
PTT	Push-To-Talk
Q-bit	ISO 8208 Qualifier bit
QOS	Quality of Service
RA	Random Access
RC	Raised Cosine
REJ	Reject
RF	Radio Frequency
RFI	Radio Frequency Interference
RM	Reject Mode
rms	Root Mean Square
RNR	Receiver Not Ready (Frame)
RPOA	recognized private operating agencies
RR	Receiver Ready (Frame)
RS	Reed-Solomon
RSP	Response (Frame)
RTS	Request to Send
RWS	Remote Wait State

SATCOM	Satellite Communication System
SDL	Specification and Description Language
SDU	Service Data Unit
SIGMET	Significant Meteorological Information
SME	System Management Entity
SMI	Standard Message Identifiers
SMT	Standard Message Text
SN	Subnetwork
SNAcP	Subnetwork Access Protocol
SNDCF	Subnetwork Dependent Convergence Function
SNPA	Subnetwork Point of Attachment
SNR	Signal to Noise Ratio
SNR	Sequence Number Received
SNS	Subnetwork Service
SNSAP	Subnetwork Service Access Point
SP	Supervisory Packet
SQP	Signal Quality Parameter
SREJ	Selective Reject (Frame)
SRM	Sent Selective Reject Mode
SU	Signal Unit
SVC	Switched Virtual Circuit
TDMA	Time Division Multiple Access
TEI	Text Element Identifiers
TRP	Timing Reference Point
TS	Timing State

TSO	Technical Standard Order
UA	Unnumbered Acknowledgment (Frame)
UDR	Urgent Downlink Request
UI	Unnumbered Information (Frame)
V	Voice
VC	Virtual Circuit
V/D	Voice or Data
VDL	VHF Digital Link
VHF	Very High Frequency
VME	VDL Management Entity
VSDA	VDL Specific DTE Addressing
VSP	VDL Supervisory Packet
XID	Exchange ID (Frame)
XOR	Exclusive OR

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Appendix D

System Link Margin Comparison of D8PSK and DSB-AM

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This analysis compares the link margin of the proposed 31.5 kbps D8PSK waveform with that of the present DSB-AM waveform. A communication range of 200 nmi is used for the comparison. Transmitter carrier power and the ground antenna systems are equal for both systems. Experience with digital voice systems indicates that good quality digital voice can be achieved at a BER of 0.01 when the encoding rate is 4800 bps. Generally, DSB-AM systems are engineered to provide an SNR of at least 9.54 dB or greater. This corresponds to a (S + N)/N ratio of 10 d**B**. The comparison table assumes that these two benchmarks are roughly equivalent. If not, the table should be adjusted. The table shows that at 200 nmi both modulations have positive margin. The D8PSK has a margin of 4.09 dB, and DSB-AM system has a margin of 5.79 dB.

The parameters in Table D-1 are based on the information contained in Table 3-98. The analyses for both waveforms are the same down to the row listing the carrier-to-noise ratio (C/No). The effective noise figure listed in the table is 17.79 dB. This effective noise figure comprises an external noise figure of 20 dB and a receiver noise figure of 10 dB. Since the effective noise figure is referred to the input to the receiver, the 20 dB external noise figure is reduced by the 3 dB cable loss prior to combining with the 10 dB receiver noise figure.

For the AM system, C/N_o needs to be adjusted by a modulation index (m) factor and by the post-detection audio bandwidth (PDBW). The following relationship can be readily developed.

$$SNR = C\,(m^2/2)/kT_oBF$$

where

$C\,(m^2/2)$ = the received pre-detection sideband power

B = the post-detection receiver bandwidth (PDBW)

F = the receive system noise figure

In the table, B = 3000 Hz and m = 0.3.

For the D8PSK system, the necessary adjustments include a loss associated with the use of a raised-cosine (RC) transmit filter instead of an ideal root-raised-cosine (RRC) filter. (The RRC filter would allow a matched RRC filter to be used by the receiver without generating unwanted intersymbol interference.) This loss amounts to approximately 1.8 dB. An additional 2.2 dB is allowed for implementation losses. (Note that no such implementation loss is included in the DSB-AM budget.)

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Table D-1: Margin Comparison for D8PSK (Voice) and DSB-AM (Voice)

	D8PSK	DSB-AM
Transmit power (dBm)	41.76	41.76
Cable loss (A/C) (dB)	-3.00	-3.00
Antenna gain (A/C) (dBi)	-4.00	-4.00
FSPL (dB)	-126.55	-126.55
Antenna gain (gnd) (dBi)	2.15	2.15
Cable loss (gnd) (dB)	-3.00	-3.00
Received power (gnd) (dBm)	-92.64	-92.64
Receiver F (dB)	10.00	10.00
External F (dB)	20.00	20.00
Effective F (dB)	17.79	17.79
kT_o (dBm/Hz)	-174.00	-174.00
kT_oF (dBm/Hz)	-156.21	-156.21
C/N_o (dB Hz)	63.57	63.57
Bit Rate (dB Hz)	44.98	
Implementation loss Transmitter (dB)	1.00	
Implementation loss Receiver (dB)	1.20	
Received E_b/N_o (dB)	16.39	
Required E_b/N_o (ideal)* (dB)	10.50	
Required E_b/N_o (RC filter) (dB)	12.30	
AM modulation factor(dB)		-13.47
PDBW (dB Hz)		34.77
Received SNR (dB)		15.33
Required SNR* (dB)		9.54
Margin (dB)	4.09	5.79

* Required E_b/N_o and SNR may need to be adjusted to account for relative performance of the 4800 bps vocoder and DSB-AM

Appendix E

VDL Mode 2 Generator Polynomial g(X)

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Appendix E: VDL Mode 2 Generator Polynomial g(X)

From the VDL Mode 2 requirement: $g(X)=(X+\%^{120})(X+\%^{121})...(X+\%^{125})$

where % is a primitive element of Galois field GF(256).

To construct a Galois field with 2^8 elements use the prime polynomial of degree 8 as specified in the VDL Mode 2 requirements:

$p(x)=x^8+x^7+x^2+x+1$

Following these steps, the generator polynomial for VDL is:

$x^6+\%^{176}x^5+\%^{186}x^4+\%^{244}x^3+\%^{176}x^2+\%^{156}x+\%^{225}$

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Appendix F

Sample VDL Mode 2 and VDL Mode 3 Transmission Examples

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VDL Mode 2 Transmission Example

This appendix contains an example of how to encode an Applications Layer message as defined in Chapter 6 of Volume III of Annex 10 of the Convention on International Civil Aviation as per Amendment 72, hereafter referred to as the SARPs. The example below illustrates the 12 steps necessary to generate a Mode 2 message. This sample transmission consists of two frames transmitted from a ground source to an aircraft. The destination address is a 24 bit ICAO aircraft address and the source address is a fictitious address chosen to force bit stuffing for purposes of this example.

Step 1: Destination Address Computation

The destination aircraft is N24175 whose 24 bit ICAO destination address is 0xA23721. Binary representation of the destination address with LSB on the left is shown below.

```
       1      2      7      3      2      A   (Hex)
      ----   ----   ----   ----   ----   ----
(LSB) 1000   0100   1110   1100   0100   0101  (MSB)
```

The address type field is "Aircraft, 24 bit ICAO address" and the A/G bit is 1 since the transmitter is on the ground. Additional bits required for formatting are shown below and are annotated as follows: Address extension bits are noted by E, address type field bit by T, and air ground status bit by A. The complete DLS address in binary as defined in Section 3.2.2.4.2 is as follows:

```
       8      4      7      6      1      0      B      2   (Hex)
      ----   ----   ----   ----   ----   ----   ----   ----
(LSB) 1000   0100   0111   0110   0001   0000   1011   0010  (MSB)
                E             E             E      T   TTAE
```

The hex representation with octet number in parenthesis as represented in Figure 3-4 is shown below.

0x84(4) 0x76(3) 0x10(2) 0xB2(1)

Step 2: Source Address Computation

In this example, the 24 bit ground station address is 0x345678. Binary representation of the source address with the LSB on the left follows.

```
       8      7      6      5      4      3   (Hex)
      ----   ----   ----   ----   ----   ----
(LSB) 0001   1110   0110   1010   0010   1100  (MSB)
```

The address type field is "ICAO Delegated Address Space" and the C/R bit is 0 to indicate this is a command. Additional bits required for formatting are shown below and are annotated as follows: address extension bits are noted by E, address type field bit by T, and Command-Response bit by C. The complete DLS address in binary as defined in Section 3.2.2.4.2 is as follows:

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```
          1      F      3      4      8      A      9      4     (Hex)
        ----   ----   ----   ----   ----   ----   ----   ----
 (LSB)  0001   1111   0011   0100   1000   1010   1001   0100   (MSB)
                 E             E             E       T  TTCE
```

The hex representation of DLS source address with the octet number in parenthesis as represented in Figure 3-4 is shown below.

0x1F(8) 0x34(7) 0x8A(6) 0x94(5)

Step 3: Encoding of Messages

Normally data would be sent as part of a subnet packet with subnet header information in front of it. For the purposes of this illustration, this packet information has not been added and the data has been sent raw.

The following assumption is made about the state of the AVLC frame counters. The last frame received was 0, and the last frame transmitted was 0. The control octet for the first frame is encoded as an I frame with N(r)=1, N(s)=1, and P/F=0. The resulting octet is 0x22.

The first frame data is as follows:

TAF AMD KROC 081242Z 081312 04012KT 2SM RA BR SCT006 OVC015 TEMPO 1314 3SM -RA BR BKN006 OVC015\n FM1400 04012G18KT 5SM BR SCT006 OVC015 TEMPO 1420 3SM -RA BR OVC006\n FM2000 04013G20KT 5SM -RA BR BKN006 OVC012 TEMPO 2024 2SM RA BR OVC003\n FM0000 06012KT 4SM BR SCT005 OVC012 TEMPO 0012 2SM -RA BR OVC005\n

The first frame in hex, including address, control and FCS, excluding flags, with LSB transmitted first is shown below.

```
                                 Link Ctrl Field
                                       |
|← destination →|←    source     →|   |   T  A  F     A  M  D     K  R  O
----------------------------------------------------------------------------
B2 10 76 84 94 8A 34 1F 22 54 41 46 20 41 4D 44 20 4B 52 4F
43 20 30 38 31 32 34 32 5A 20 30 38 31 33 31 32 20 30 34 30
31 32 4B 54 20 32 53 4D 20 52 41 20 42 52 20 53 43 54 30 30
36 20 4F 56 43 30 31 35 20 54 45 4D 50 4F 20 31 33 31 34 20
33 53 4D 20 2D 52 41 20 42 52 20 42 4B 4E 30 30 36 20 4F 56
43 30 31 35 0A 20 46 4D 31 34 30 30 20 30 34 30 31 32 47 31
38 4B 54 20 35 53 4D 20 42 52 20 53 43 54 30 30 36 20 4F 56
43 30 31 35 20 54 45 4D 50 4F 20 31 34 32 30 20 33 53 4D 20
2D 52 41 20 42 52 20 4F 56 43 30 30 36 0A 20 46 4D 32 30 30
30 20 30 34 30 31 33 47 32 30 4B 54 20 35 53 4D 20 2D 52 41
20 42 52 20 42 4B 4E 30 30 36 20 4F 56 43 30 31 32 20 54 45
4D 50 4F 20 32 30 32 34 20 32 53 4D 20 52 41 20 42 52 20 4F
56 43 30 30 33 0A 20 46 4D 30 30 30 30 20 30 36 30 31 32 4B
54 20 34 53 4D 20 42 52 20 53 43 54 30 30 35 20 4F 56 43 30
```

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```
31 32 20 54 45 4D 50 4F 20 30 30 31 32 20 32 53 4D 20 2D 52
41 20 42 52 20 4F 56 43 30 30 35 0A 44 BF
---------------------------------------
 A     B  R     O  V  C  0  0  5  \n  |  |
                                      |  |
        Per Figure 3-4:  Frame Check Sequence MSO   Frame Check Sequence LSO
```

The control octet for the second frame is encoded as an I frame with N(r)=1, N(s)=2, and P/F=1. The resulting octet is 0x34.

The second frame data is as follows:

METAR KROC 081354Z 03014KT 6SM -RA BR BKN004 OVC010 01/01 A2966 RMK AO2 SLP050 LK TMP 39\nMETAR KDCA 081353Z 18008KT 2SM -DZ BR OVC006 17/17 A2993 RMK DZB44 CIG 005V007 SLP135\n

The second frame in hex, including address, control and FCS, excluding flags with LSB transmitted first is shown below.

```
                        Link Ctrl Field
                              |
|← destination →|←  source  →|  |  M  E  T  A  R     K  R  O  C
-----------------------------------------------------------------
B2 10 76 84 94 8A 34 1F 34 4D 45 54 41 52 20 4B 52 4F 43 20
30 38 31 33 35 34 5A 20 30 33 30 31 34 4B 54 20 36 53 4D 20
2D 52 41 20 42 52 20 42 4B 4E 30 30 34 20 4F 56 43 30 31 30
20 30 31 2F 30 31 20 41 32 39 36 36 20 52 4D 4B 20 41 4F 32
20 53 4C 50 30 35 30 20 4C 4B 20 54 4D 50 20 33 39 0A 4D 45
54 41 52 20 4B 44 43 41 20 30 38 31 33 35 33 5A 20 31 38 30
30 38 4B 54 20 32 53 4D 20 2D 44 5A 20 42 52 20 4F 56 43 30
30 36 20 31 37 2F 31 37 20 41 32 39 39 33 20 52 4D 4B 20 44
5A 42 34 34 20 43 49 47 20 30 30 35 56 30 30 37 20 53 4C 50
31 33 35 0A 3E F9
-----------------
 1  3  5  \n  |  |
              |  |
   Frame Check    Frame Check Sequence LSO
  Sequence MSO   (per Figure 3-4)
```

Step 4: Flag Insertion

Flags are inserted at the beginning and end of the transmission and between each frame. The complete transmission in hex with flags inserted is shown below. For clarity, the three flags are shown in bold. The flags are not bit stuffed in step 5 below, but are included here to show relative position in the datastream.

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```
7E B2 10 76 84 94 8A 34 1F 22 54 41 46 20 41 4D 44 20 4B 52
4F 43 20 30 38 31 32 34 32 5A 20 30 38 31 33 31 32 20 30 34
30 31 32 4B 54 20 32 53 4D 20 52 41 20 42 52 20 53 43 54 30
30 36 20 4F 56 43 30 31 35 20 54 45 4D 50 4F 20 31 33 31 34
20 33 53 4D 20 2D 52 41 20 42 52 20 42 4B 4E 30 30 36 20 4F
56 43 30 31 35 0A 20 46 4D 31 34 30 30 20 30 34 30 31 32 47
31 38 4B 54 20 35 53 4D 20 42 52 20 53 43 54 30 30 36 20 4F
56 43 30 31 35 20 54 45 4D 50 4F 20 31 34 32 30 20 33 53 4D
20 2D 52 41 20 42 52 20 4F 56 43 30 30 36 0A 20 46 4D 32 30
30 30 20 30 34 30 31 33 47 32 30 4B 54 20 35 53 4D 20 2D 52
41 20 42 52 20 42 4B 4E 30 30 36 20 4F 56 43 30 31 32 20 54
45 4D 50 4F 20 32 30 32 34 20 32 53 4D 20 52 41 20 42 52 20
4F 56 43 30 30 33 0A 20 46 4D 30 30 30 30 20 30 36 30 31 32
4B 54 20 34 53 4D 20 42 52 20 53 43 54 30 30 35 20 4F 56 43
30 31 32 20 54 45 4D 50 4F 20 30 30 31 32 20 32 53 4D 20 2D
52 41 20 42 52 20 4F 56 43 30 30 35 0A 44 BF 7E B2 10 76 84
94 8A 34 1F 34 4D 45 54 41 52 20 4B 52 4F 43 20 30 38 31 33
35 34 5A 20 30 33 30 31 34 4B 54 20 36 53 4D 20 2D 52 41 20
42 52 20 42 4B 4E 30 30 34 20 4F 56 43 30 31 30 20 30 31 2F
30 31 20 41 32 39 36 36 20 52 4D 4B 20 41 4F 32 20 53 4C 50
30 35 30 20 4C 4B 20 54 4D 50 20 33 39 0A 4D 45 54 41 52 20
4B 44 43 41 20 30 38 31 33 35 33 5A 20 31 38 30 30 38 4B 54
20 32 53 4D 20 2D 44 5A 20 42 52 20 4F 56 43 30 30 36 20 31
37 2F 31 37 20 41 32 39 39 33 20 52 4D 4B 20 44 5A 42 34 34
20 43 49 47 20 30 30 35 56 30 30 37 20 53 4C 50 31 33 35 0A
3E F9 7E
```

Step 5: Bit stuffing

Bit stuffing is done according to ISO 3309 which requires an extra zero to be inserted after a sequence of 5 ones, not including a flag. The bit stuffed data is shown in hex below. Bit stuffing is not applied to flag (0x7E) characters. The first bit stuff occurs in the tenth byte, 0x44, causing it and all following bytes to be different from the original data.

```
7E B2 10 76 84 94 8A 34 1F 44 A8 82 8C 40 82 9A 88 40 96 A4
9E 86 40 60 70 62 64 68 64 B4 40 60 70 62 66 62 64 40 60 68
60 62 64 96 A8 40 64 A6 9A 40 A4 82 40 84 A4 40 A6 86 A8 60
60 6C 40 9E AC 86 60 62 6A 40 A8 8A 9A A0 9E 40 62 66 62 68
40 66 A6 9A 40 5A A4 82 40 84 A4 40 84 96 9C 60 60 6C 40 9E
AC 86 60 62 6A 14 40 8C 9A 62 68 60 60 40 60 68 60 62 64 8E
62 70 96 A8 40 6A A6 9A 40 84 A4 40 A6 86 A8 60 60 6C 40 9E
AC 86 60 62 6A 40 A8 8A 9A A0 9E 40 62 68 64 60 40 66 A6 9A
40 5A A4 82 40 84 A4 40 9E AC 86 60 60 6C 14 40 8C 9A 64 60
60 60 40 60 68 60 62 66 8E 64 60 96 A8 40 6A A6 9A 40 5A A4
82 40 84 A4 40 84 96 9C 60 60 6C 40 9E AC 86 60 62 64 40 A8
8A 9A A0 9E 40 64 60 64 68 40 64 A6 9A 40 A4 82 40 84 A4 40
```

```
9E AC 86 60 60 66 14 40 8C 9A 60 60 60 60 40 60 6C 60 62 64
96 A8 40 68 A6 9A 40 84 A4 40 A6 86 A8 60 60 6A 40 9E AC 86
60 62 64 40 A8 8A 9A A0 9E 40 60 60 62 64 40 64 A6 9A 40 5A
A4 82 40 84 A4 40 9E AC 86 60 60 6A 14 88 BE FA C9 42 D8 11
52 2A D2 7C A0 69 2A A2 0A 92 02 59 92 7A 1A 02 81 C1 89 99
A9 A1 D1 02 81 99 81 89 A1 59 A2 02 B1 99 6A 02 69 91 0A 02
11 92 02 11 5A 72 82 81 A1 01 79 B2 1A 82 89 81 01 81 89 79
81 89 01 09 92 C9 B1 B1 01 91 6A 5A 02 09 7A 92 01 99 62 82
82 A9 81 01 61 5A 02 A1 6A 82 02 99 C9 51 68 2A A2 0A 92 02
59 22 1A 0A 02 81 C1 89 99 A9 99 D1 02 89 C1 81 81 C1 59 A2
02 91 99 6A 02 69 21 D2 02 11 92 02 79 B2 1A 82 81 B1 01 89
B9 79 89 B9 01 09 92 C9 C9 99 01 91 6A 5A 02 21 D2 12 A2 A1
01 19 4A 3A 02 81 81 A9 B1 82 81 B9 01 99 62 82 8A 99 A9 51
F0 91 CF plus five extra bits 0x0F, transmitted 1 1 1 1 0.
```

Step 6: Length Computation

The transmission length is calculated as 503 complete octets plus 5 extra bits, for a total of 4029 bits. The 3 reserved bits are encoded as 000. The header parity bits are computed and the resulting header in binary with the leftmost bit transmitted first is shown below.

```
          000  10111101111100000  01110
           |            |              |
      Reserved       Length           FEC
```

Step 7: Padding the Final Octet

If the final octet after bit stuffing does not contain 8 bits, it is padded with 0's (which are transmitted) before being interleaved. The last octet 0x0F consists of 5 data bits on the right and three zero pad bits. After padding, the final two lines of data in step 5 in hex are shown below.

```
01 19 4A 3A 02 81 81 A9 B1 82 81 B9 01 99 62 82 8A 99 A9 51
F0 91 CF 0F
```

Step 8: Separate Message into Interleaver Blocks

The burst is divided into 249 octet blocks. The first two interleaver blocks contain 249 octets and the final block contains six octets as show below.

Block 1

```
7E B2 10 76 84 94 8A 34 1F 44 A8 82 8C 40 82 9A 88 40 96 A4
9E 86 40 60 70 62 64 68 64 B4 40 60 70 62 66 62 64 40 60 68
60 62 64 96 A8 40 64 A6 9A 40 A4 82 40 84 A4 40 A6 86 A8 60
60 6C 40 9E AC 86 60 62 6A 40 A8 8A 9A A0 9E 40 62 66 62 68
40 66 A6 9A 40 5A A4 82 40 84 A4 40 84 96 9C 60 60 6C 40 9E
AC 86 60 62 6A 14 40 8C 9A 62 68 60 60 40 60 68 60 62 64 8E
62 70 96 A8 40 6A A6 9A 40 84 A4 40 A6 86 A8 60 60 6C 40 9E
```

```
AC 86 60 62 6A 40 A8 8A 9A A0 9E 40 62 68 64 60 40 66 A6 9A
40 5A A4 82 40 84 A4 40 9E AC 86 60 60 6C 14 40 8C 9A 64 60
60 60 40 60 68 60 62 66 8E 64 60 96 A8 40 6A A6 9A 40 5A A4
82 40 84 A4 40 84 96 9C 60 60 6C 40 9E AC 86 60 62 64 40 A8
8A 9A A0 9E 40 64 60 64 68 40 64 A6 9A 40 A4 82 40 84 A4 40
9E AC 86 60 60 66 14 40 8C
```

Block 2

```
9A 60 60 60 60 40 60 6C 60 62 64 96 A8 40 68 A6 9A 40 84 A4
40 A6 86 A8 60 60 6A 40 9E AC 86 60 62 64 40 A8 8A 9A A0 9E
40 60 60 62 64 40 64 A6 9A 40 5A A4 82 40 84 A4 40 9E AC 86
60 60 6A 14 88 BE FA C9 42 D8 11 52 2A D2 7C A0 69 2A A2 0A
92 02 59 92 7A 1A 02 81 C1 89 99 A9 A1 D1 02 81 99 81 89 A1
59 A2 02 B1 99 6A 02 69 91 0A 02 11 92 02 11 5A 72 82 81 A1
01 79 B2 1A 82 89 81 01 81 89 79 81 89 01 09 92 C9 B1 B1 01
91 6A 5A 02 09 7A 92 01 99 62 82 82 A9 81 01 61 5A 02 A1 6A
82 02 99 C9 51 68 2A A2 0A 92 02 59 22 1A 0A 02 81 C1 89 99
A9 99 D1 02 89 C1 81 81 C1 59 A2 02 91 99 6A 02 69 21 D2 02
11 92 02 79 B2 1A 82 81 B1 01 89 B9 79 89 B9 01 09 92 C9 C9
99 01 91 6A 5A 02 21 D2 12 A2 A1 01 19 4A 3A 02 81 81 A9 B1
82 81 B9 01 99 62 82 8A 99
```

Block 3

A9 51 F0 91 CF 0F plus 243 untransmitted virtual fill octets for a total of 249 octets.

Step 9: Reed Solomon FEC Computation on Interleaver Blocks

Before the data is clocked into the encoder, the contents of the shift register b=[b0..b5] are reset to 0x00. The 249 data octets are then clocked into the encoder. The order of transmission of octets into the encoder is from left to right. In this example, the first octet of the first interleaver block is the flag character (0x7E). For purposes of the encoder, the most significant bit of each byte forms the most significant bit of the Reed Solomon symbol.

The FEC computation is depicted in Figure F-1.

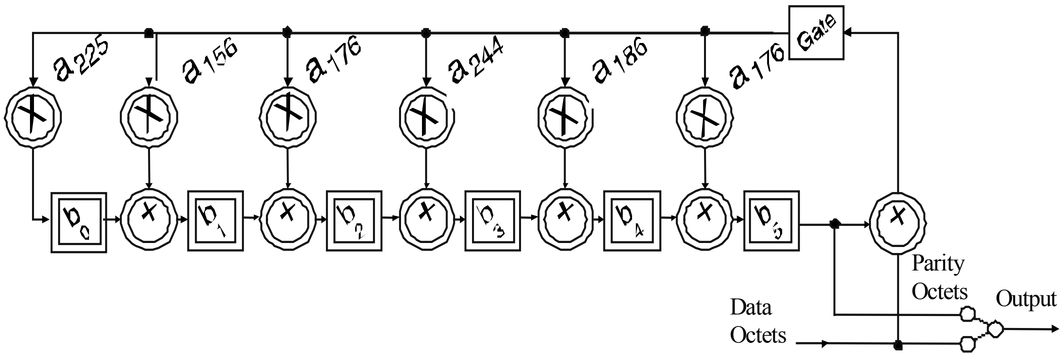

Figure F-1: **FEC Computation**

After the first interleaver block of data has been shifted into the encoder, the contents of the shift registers are: b=[b_0..b_5]=[1E C6 BB FC 1E AD]

The parity octets are then clocked out of the encoder and appended to the interleaver block. The first parity octet out of the encoder is b_5 and the last is b_0. The first octet out of the encoder is placed in column 250 of the interleaver and the last in column 255.

The FEC is computed on each interleaver block shown below.

Block 1: `AD 1E FC BB C6 1E`
Block 2: `54 F0 E6 5B E5 E6`
Block 3: `48 2C 7E 3D BE 1D`

A complete interleaver block, including data and parity, is shown below. For brevity, only the first interleaver block is shown.

Block 1 including parity octets

```
7E B2 10 76 84 94 8A 34 1F 44 A8 82 8C 40 82 9A 88 40 96 A4
9E 86 40 60 70 62 64 68 64 B4 40 60 70 62 66 62 64 40 60 68
60 62 64 96 A8 40 64 A6 9A 40 A4 82 40 84 A4 40 A6 86 A8 60
60 6C 40 9E AC 86 60 62 6A 40 A8 8A 9A A0 9E 40 62 66 62 68
40 66 A6 9A 40 5A A4 82 40 84 A4 40 84 96 9C 60 60 6C 40 9E
AC 86 60 62 6A 14 40 8C 9A 62 68 60 60 40 60 68 60 62 64 8E
62 70 96 A8 40 6A A6 9A 40 84 A4 40 A6 86 A8 60 60 6C 40 9E
AC 86 60 62 6A 40 A8 8A 9A A0 9E 40 62 68 64 60 40 66 A6 9A
40 5A A4 82 40 84 A4 40 9E AC 86 60 60 6C 14 40 8C 9A 64 60
60 60 40 60 68 60 62 66 8E 64 60 96 A8 40 6A A6 9A 40 5A A4
82 40 84 A4 40 84 96 9C 60 60 6C 40 9E AC 86 60 62 64 40 A8
8A 9A A0 9E 40 64 60 64 68 40 64 A6 9A 40 A4 82 40 84 A4 40
9E AC 86 60 60 66 14 40 8C AD 1E FC BB C6 1E
```

Step 10: Interleaved data

The data is taken out of the interleavers by columns. Only the non-fill data is transmitted. In the third interleaver block, the first 6 data octets plus the first two of the six RS FEC octets are transmitted. Thus the transmitted sequence of rows (r) and columns (c) is r1c1, r2c1, r3c1, r1c2, r2c2, r3c2, ..., r1c6, r2c6, r3c6, r1c7, r2c7, r1c8, r2c8, ..., r1c249, r2c249, r1c250, r2c250, r3c250, r1c251, r2c251, r3c251, r1c252, r2c252, r1c253, r2c253, r1c254, r2c254, r1c255, r2c255.

The hex interleaved data is shown below.

```
7E 9A A9 B2 60 51 10 60 F0 76 60 91 84 60 CF 94 40 0F 8A 60
34 6C 1F 60 44 62 A8 64 82 96 8C A8 40 40 82 68 9A A6 88 9A
40 40 96 84 A4 A4 9E 40 86 A6 40 86 60 A8 70 60 62 60 64 6A
68 40 64 9E B4 AC 40 86 60 60 70 62 62 64 66 40 62 A8 64 8A
40 9A 60 A0 68 9E 60 40 62 60 64 60 96 62 A8 64 40 40 64 64
A6 A6 9A 9A 40 40 A4 5A 82 A4 40 82 84 40 A4 84 40 A4 A6 40
86 9E A8 AC 60 86 60 60 6C 60 40 6A 9E 14 AC 88 86 BE 60 FA
62 C9 6A 42 40 D8 A8 11 8A 52 9A 2A A0 D2 9E 7C 40 A0 62 69
66 2A 62 A2 68 0A 40 92 66 02 A6 59 9A 92 40 7A 5A 1A A4 02
82 81 40 C1 84 89 A4 99 40 A9 84 A1 96 D1 9C 02 60 81 60 99
6C 81 40 89 9E A1 AC 59 86 A2 60 02 62 B1 6A 99 14 6A 40 02
8C 69 9A 91 62 0A 68 02 60 11 60 92 40 02 60 11 68 5A 60 72
62 82 64 81 8E A1 62 01 70 79 96 B2 A8 1A 40 82 6A 89 A6 81
9A 01 40 81 84 89 A4 79 40 81 A6 89 86 01 A8 09 60 92 60 C9
6C B1 40 B1 9E 01 AC 91 86 6A 60 5A 62 02 6A 09 40 7A A8 92
8A 01 9A 99 A0 62 9E 82 40 82 62 A9 68 81 64 01 60 61 40 5A
66 02 A6 A1 9A 6A 40 82 5A 02 A4 99 82 C9 40 51 84 68 A4 2A
40 A2 9E 0A AC 92 86 02 60 59 60 22 6C 1A 14 0A 40 02 8C 81
9A C1 64 89 60 99 60 A9 60 99 40 D1 60 02 68 89 60 C1 62 81
66 81 8E C1 64 59 60 A2 96 02 A8 91 40 99 6A 6A A6 02 9A 69
40 21 5A D2 A4 02 82 11 40 92 84 02 A4 79 40 B2 84 1A 96 82
9C 81 60 B1 60 01 6C 89 40 B9 9E 79 AC 89 86 B9 60 01 62 09
64 92 40 C9 A8 C9 8A 99 9A 01 A0 91 9E 6A 40 5A 64 02 60 21
64 D2 68 12 40 A2 64 A1 A6 01 9A 19 40 4A A4 3A 82 02 40 81
84 81 A4 A9 40 B1 9E 82 AC 81 86 B9 60 01 60 99 66 62 14 82
40 8A 8C 99 AD 54 48 1E F0 2C FC E6 BB 5B C6 E5 1E E6
```

Step 11: Unique Word

The unique word, reserved symbol, and length field of the data are added to the beginning of the message. The unique word, header length and first two interleaved data octets are shown as unscrambled tribits, with the left-most bit transmitted first. The first line of data is the unique word; and the second line is the user data, beginning with the VDL header (reserved symbol, length, and header FEC.)

```
000 010 011 110 000 001 101 110 001 100 011 111 101 111 100 010
000 101 111 011 111 000 000 111 001 111 110 010 110 01
```

Step 12: Scrambled Data

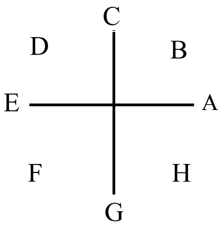

Figure F-2: Absolute Phase Encoding (Gray code)

The notation below provides the symbol bit value, followed by the corresponding absolute phase value. The absolute phase value for each symbol is calculated by applying the change in phase prescribed for the symbol value by Table 3-1 to the absolute phase of the previous symbol.

The first few values can be interpreted as follows. For this example, the initial phase is assumed to be A. The value 000 causes a phase change of 0 pi, so the phase remains A. Next, the symbol value of 010 causes a phase change of 3/4 pi, so the phase changes from A to D. Next, the symbol value of 011 causes a phase change of 4/4 (1) pi, so the phase changes from F to B. This process continues throughout Figure F-2.

The absolute phase encoding is shown in Figure F-2. The complete transmission in binary representation is shown below. Databits after the unique word are scrambled. The message consists of 48 bits of unique word, 25 bits of header, 4032 bits of data (504 octets), and 112 bits of Reed Solomon FEC (6 + 6 + 2 octets) for a total of 4217 bits. One extra bit is added to make an integer number of symbols. Thus the total symbol count is 1406. The data is transmitted leftmost bit first.

```
000-A 010-D 011-F 110-B 000-B 001-C 101-A 110-E 001-F 100-E
011-G 111-D 101-B 111-G 100-F 010-A 000-A 001-B 001-C 010-F
010-A 111-F 000-F 011-H 000-H 110-D 100-C 010-F 001-G 101-E
000-E 110-A 101-G 100-F 110-B 110-F 110-B 010-E 001-F 000-F
011-H 011-B 101-H 110-D 111-A 110-E 011-G 110-C 110-G 110-C
010-F 010-A 000-A 000-A 101-G 100-F 111-C 010-F 111-C 110-G
001-H 111-E 011-G 101-E 000-E 101-C 010-F 000-F 111-C 101-A
111-F 010-A 001-B 111-G 110-C 111-H 101-F 100-E 100-D 011-F
010-A 001-B 001-C 100-B 111-G 100-F 101-D 001-E 010-H 101-F
010-A 100-H 010-C 000-C 000-C 101-A 111-F 001-G 110-C 011-E
010-H 000-H 000-H 100-G 101-E 010-H 010-C 011-E 010-H 100-G
111-D 100-C 101-A 010-D 110-H 111-E 001-F 011-H 101-F 100-E
000-E 101-C 000-C 011-E 100-D 100-C 101-A 001-B 010-E 010-H
010-C 000-C 001-D 110-H 001-A 100-H 110-D 011-F 010-A 111-F
110-B 111-G 001-H 111-E 111-B 111-G 100-F 110-B 111-G 111-D
101-B 111-G 111-D 101-B 000-B 010-E 010-H 001-A 110-E 000-E
111-B 110-F 011-H 100-G 000-G 111-D 101-B 001-C 100-B 000-B
```

```
011-D 000-D 011-F 100-E 101-C 010-F 111-C 100-B 110-F 000-F
111-C 001-D 101-B 011-D 001-E 001-F 111-C 111-H 111-E 010-H
000-H 010-C 011-E 010-H 010-C 101-A 010-D 110-H 101-F 000-F
011-H 110-D 101-B 000-B 100-A 111-F 011-H 001-A 010-D 111-A
111-F 101-D 111-A 111-F 110-B 010-E 000-E 000-E 100-D 010-G
111-D 101-B 001-C 111-H 010-C 100-B 011-D 000-D 110-H 000-H
110-D 100-C 111-H 110-D 001-E 000-E 000-E 000-E 011-G 011-A
010-D 011-F 010-A 101-G 101-E 110-A 000-A 000-A 010-D 101-B
010-E 011-G 101-E 001-F 010-A 100-H 111-E 101-C 111-H 110-D
100-C 110-G 110-C 101-A 111-F 101-D 010-G 100-F 101-D 001-E
000-E 011-G 101-E 111-B 111-G 011-A 111-F 010-A 111-F 101-D
010-G 011-A 101-G 001-H 011-B 000-B 000-B 110-F 110-B 110-F
001-G 111-D 111-A 110-E 101-C 000-C 010-F 000-F 001-G 000-G
101-E 000-E 010-H 001-A 011-C 101-A 110-E 010-H 110-D 111-A
100-H 101-F 011-H 101-F 000-F 111-C 001-D 001-E 001-F 111-C
101-A 000-A 011-C 000-C 011-E 010-H 000-H 010-C 110-G 110-C
101-A 001-B 010-E 110-A 011-C 110-G 111-D 000-D 010-G 110-C
011-E 111-B 000-B 100-A 000-A 000-A 111-F 011-H 000-H 011-B
001-C 110-G 100-F 010-A 100-H 111-E 001-F 100-E 001-F 110-B
001-C 111-H 001-A 010-D 101-B 010-E 110-A 001-B 011-D 000-D
010-G 110-C 011-E 001-F 010-A 011-C 101-A 101-G 111-D 100-C
101-A 000-A 000-A 001-B 101-H 000-H 001-A 001-B 010-E 011-G
011-A 110-E 111-B 100-A 111-F 010-A 111-F 100-E 011-G 101-E
010-H 010-C 000-C 000-C 001-D 100-C 100-B 011-D 011-F 000-F
010-A 000-A 101-G 011-A 110-E 101-C 001-D 100-C 001-D 000-D
001-E 000-E 010-H 100-G 101-E 101-C 010-F 001-G 011-A 111-F
011-H 111-E 000-E 010-H 001-A 001-B 000-B 100-A 001-B 100-A
100-H 100-G 110-C 011-E 100-D 010-G 011-A 011-C 000-C 100-B
110-F 110-B 110-F 000-F 001-G 010-B 111-G 101-E 110-A 101-G
110-C 001-D 000-D 100-C 011-E 111-B 101-H 110-D 101-B 000-B
010-E 010-H 001-A 010-D 001-E 001-F 011-H 000-H 010-C 111-H
011-B 110-F 101-D 010-G 000-G 100-F 010-A 001-B 011-D 011-F
001-G 001-H 110-D 110-H 111-E 111-B 011-D 010-G 100-F 010-A
101-G 001-H 010-C 111-H 100-G 000-G 011-A 000-A 101-G 011-A
111-F 101-D 101-B 001-C 101-A 100-H 000-H 110-D 111-A 100-H
010-C 100-B 011-D 000-D 001-E 001-F 111-C 010-F 010-A 111-F
000-F 011-H 010-C 011-E 110-A 100-H 110-D 001-E 001-F 000-F
110-B 100-A 100-H 011-B 101-H 111-E 100-D 101-B 011-D 101-B
101-H 000-H 010-C 011-E 001-F 101-D 001-E 001-F 110-B 001-C
011-E 010-H 011-B 110-F 011-H 011-B 010-E 100-D 001-E 101-C
101-A 110-E 110-A 010-D 000-D 010-G 101-E 001-F 010-A 001-B
000-B 000-B 111-G 101-E 000-E 000-E 101-C 111-H 010-C 111-H
011-B 110-F 011-H 101-F 000-F 000-F 011-H 100-G 001-H 010-C
111-H 110-D 110-H 010-C 001-D 110-H 010-C 101-A 001-B 111-G
100-F 010-A 100-H 011-B 100-A 011-C 011-E 011-G 001-H 010-C
010-F 001-G 011-A 100-H 010-C 101-A 101-G 010-B 000-B 001-C
110-G 110-C 011-E 001-F 111-C 000-C 110-G 010-B 001-C 101-A
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110-E 001-F 010-A 110-E 100-D 001-E 011-G 101-E 011-G 000-G
000-G 001-H 011-B 101-H 110-D 000-D 000-D 101-B 100-A 101-G
100-F 010-A 000-A 011-C 111-H 110-D 010-G 101-E 000-E 110-A
110-E 100-D 000-D 000-D 110-H 011-B 001-C 111-H 000-H 111-E
010-H 001-A 110-E 100-D 110-H 101-F 110-B 111-G 010-B 111-G
000-G 111-D 010-G 010-B 011-D 101-B 100-A 010-D 101-B 111-G
011-A 111-F 111-C 110-G 000-G 001-H 011-B 111-G 111-D 100-C
111-H 011-B 100-A 000-A 100-H 111-E 101-C 100-B 010-E 010-H
100-G 110-C 100-B 101-H 011-B 001-C 100-B 111-G 101-E 001-F
001-G 011-A 110-E 011-G 011-A 101-G 100-F 000-F 000-F 001-G
010-B 110-F 101-D 011-F 011-H 111-E 000-E 101-C 001-D 001-E
011-G 001-H 000-H 110-D 010-G 110-C 100-B 000-B 010-E 100-D
100-C 001-D 011-F 111-C 010-F 101-D 110-H 101-F 100-E 010-H
110-D 010-G 110-C 110-G 111-D 111-A 001-B 101-H 111-E 110-A
010-D 011-F 110-B 101-H 010-C 001-D 110-H 000-H 011-B 100-A
110-E 000-E 100-D 111-A 011-C 110-G 010-B 010-E 010-H 000-H
001-A 110-E 001-F 110-B 011-D 100-C 010-F 010-A 110-E 110-A
110-E 000-E 111-B 010-E 111-B 110-F 001-G 001-H 101-F 010-A
000-A 101-G 000-G 110-C 110-G 011-A 011-C 011-E 100-D 010-G
100-F 000-F 011-H 011-B 010-E 110-A 110-E 011-G 011-A 110-E
010-H 101-F 000-F 000-F 110-B 000-B 011-D 111-A 010-D 011-F
101-D 000-D 101-B 111-G 011-A 101-G 000-G 101-E 010-H 111-E
010-H 101-F 000-F 100-E 111-B 100-A 101-G 100-F 100-E 100-D
000-D 101-B 111-G 001-H 100-G 010-B 010-E 001-F 000-F 111-C
001-D 111-A 001-B 000-B 001-C 011-E 101-C 100-B 111-G 011-A
001-B 100-A 001-B 111-G 111-D 110-H 010-C 000-C 011-E 111-B
100-A 110-E 100-D 011-F 001-G 000-G 110-C 011-E 011-G 100-F
011-H 101-F 100-E 100-D 111-A 101-G 001-H 001-A 100-H 010-C
001-D 010-G 110-C 000-C 000-C 010-F 110-B 111-G 010-B 011-D
111-A 000-A 110-E 001-F 010-A 000-A 101-G 011-A 111-F 110-B
111-G 111-D 011-F 110-B 010-E 100-D 011-F 011-H 111-E 000-E
010-H 011-B 111-G 010-B 101-H 111-E 011-G 110-C 011-E 110-A
100-H 001-A 000-A 011-C 011-E 010-H 100-G 100-F 011-H 110-D
011-F 100-E 100-D 010-G 010-B 011-D 101-B 000-B 011-D 101-B
111-G 011-A 000-A 010-D 010-G 110-C 110-G 011-A 100-H 011-B
011-D 001-E 111-B 010-E 111-B 001-C 101-A 011-C 001-D 000-D
101-B 000-B 010-E 100-D 010-G 100-F 000-F 100-E 101-C 001-D
101-B 000-B 101-H 111-E 011-G 101-E 100-D 110-H 101-F 111-C
111-H 111-E 010-H 110-D 011-F 000-F 100-E 101-C 000-C 011-E
011-G 000-G 100-F 110-B 010-E 110-A 001-B 100-A 010-D 100-C
110-G 001-H 010-C 011-E 001-F 011-H 001-A 100-H 011-B 101-H
001-A 010-D 000-D 001-E 110-A 110-E 010-H 011-B 100-A 000-A
011-C 111-H 001-A 110-E 010-H 011-B 100-A 101-G 001-H 110-D
001-E 111-B 011-D 110-H 001-A 011-C 110-G 010-B 011-D 011-F
000-F 001-G 110-C 001-D 111-A 110-E 011-G 110-C 100-B 111-G
101-E 011-G 100-F 110-B 001-C 111-H 100-G 011-A 000-A 011-C
011-E 111-B 101-H 110-D 100-C 110-G 001-H 000-H 111-E 101-C
```

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100-B 101-H 100-G 101-E 001-F 010-A 011-C 010-F 100-E 010-H
101-F 001-G 111-D 010-G 101-E 011-G 000-G 101-E 010-H 111-E
101-C 100-B 000-B 110-F 111-C 010-F 001-G 001-H 111-E 010-H
110-D 101-B 000-B 101-H 010-C 000-C 011-E 011-G 001-H 001-A
010-D 000-D 000-D 000-D 000-D 100-C 011-E 110-A 110-E 110-A
111-F 010-A 100-H 000-H 000-H 111-E 000-E 010-H 010-C 100-B
100-A 100-H 011-B 100-A 011-C 110-G 010-B 000-B 000-B 000-B
101-H 110-D 010-G 110-C 001-D 101-B 010-E 000-E 101-C 000-C
011-E 010-H 001-A 111-F 111-C 001-D 000-D 000-D 111-A 101-G
111-D 110-H 110-D 001-E 011-G 110-C 011-E 100-D 010-G 000-G
111-D 111-A 101-G 101-E 001-F 011-H 011-B 101-H 011-B 101-H
011-B 010-E 011-G 100-F 101-D 001-E 011-G 110-C 101-A 011-C
001-D 000-D 110-H 000-H 111-E 011-G 000-G 110-C 110-G 011-A
010-D 100-C 101-A 111-F 011-H 100-G 000-G 001-H 100-G 010-B
011-D 110-H 101-F 000-F 111-C 111-H 001-A 010-D 001-E 111-B
110-F 110-B 000-B 100-A 000-A 000-A 001-B 001-C 111-H 100-G
111-D 010-G 101-E 000-E 100-D 110-H 000-H 000-H 010-C 010-F
101-D 100-C 111-H 010-C 100-B 110-F 000-F 011-H 011-B 100-A
110-E 011-G 011-A 010-D 100-C 010-F 100-E 000-E 011-G 111-D
100-C 100-B 111-G 101-E 110-A 011-C 111-H 001-A 001-B 110-F
111-C 001-D 111-A 100-H 010-C 001-D 101-B 011-D 100-C 011-E
011-G 001-H 101-F 101-D 001-E 001-F 000-F 010-A 011-C 110-G
011-A 001-B 000-B 101-H 101-F 101-D 000-D 000-D 010-G 011-A
101-G 000-G 000-G 100-F 000-F 101-D 001-E 011-G 100-F 000-F
000-F 011-H 000-H 011-B 111-G 010-B 000-B 010-E 100-D 100-C
110-G 101-E 110-A 001-B 010-E 110-A 011-C 001-D 001-E 101-C
100-B 101-H 100-G 001-H 100-G 111-D 110-H 100-G 001-H 001-A
000-A 100-H 001-A 011-C 110-G 101-E 100-D 111-A 000-A 100-H
001-A 100-H 000-H 101-F 000-F 100-E 100-D 010-G 001-H 111-E
000-E 111-B 110-F 001-G 110-C 111-H
```

VDL Mode 3 Transmission Example

In order to clarify the description of the processing necessary to transmit a VDL TDMA burst, this note will give a specific example. The example should provide a concrete definition of the correct order in which the bits should be transmitted. For this example, it will be assumed that the message is a downlink voice (V/D) burst transmitted by an aircraft unit whose Local ID is B27 (i.e., Group ID = B and Aircraft ID = 27). It is also assumed that the burst is not the last one in the voice message so that EOM = 0.

The burst consists of five segments. The first segment is the ramp-up sequence which consists of up to 5 symbols. This is followed by the V/D synchronization sequence. This is followed by the V/D (voice) header, the actual voice data, and a ramp-down sequence of up to 5 symbols. These segments will be written down explicitly below. Note that the transmitted signal uses 8-ary coding so that an octal notation is the natural one to use in describing the waveform. In the following description, binary and/or octal notation will be used where appropriate.

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(1) The ramp-up sequence consists of all zeros. In octal notation this is

00000 [octal]

(2) The synchronization sequence is

0732041245361657 [octal]

(3) The header is a 24-bit Golay codeword. The information content is formatted as follows:

{(Message ID: 3) (Local ID: 8) (EOM: 1)}

with Message ID = 001. In this example, the Local ID is B27, or 01011011. The EOM bit is 0, so that the entire header is

001010110110 [binary]

This header information is used (in the order shown) with the Golay encoder matrix to give the complete Golay codeword:

000001110111001010110110 [binary]

In octal notation this is

01671266 [octal]

(4) The voice information will depend on the specific voice message being transmitted.

(5) The ramp-down sequence consists of all zeros. In octal notation this is

00 [octal]

When all the segments are combined the transmitted sequence is

00000 {0732041245361657} 01671266 {VOICE INFO} 00 [octal]
ramp synch header* voice* ramp

The asterisk (*) added to the header and voice segments indicates that these should be subject to bit scrambling. Thus, the header bits and the voice information bits should be added (modulo 2) to the output of the PN generator described in Section 3.2.1.6 of the VDL MASPS prior to conversion into symbols. For the sake of clarity, this step is omitted in this description.

The symbol sequence above must be translated into a sequence of phases prior to transmission. The first step in this process is the translation of the symbol sequence into a sequence of phase changes. The rule for converting the symbol sequence into a phase-change sequence is given in the conversion table below.

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Symbol		**$\Delta\phi = \pi h/4$**
Binary	Octal	h
000	0	0
001	1	1
010	2	3
011	3	2
100	4	7
101	5	6
110	6	4
111	7	5

This conversion implements a Gray code, so that neighboring symbols differ by only one bit. The result is

00000 {0523071376241465} 01451344 {VOICE INFO} 00.

Finally, these phase differences are summed to give the actual transmitted phase sequence

00000 {0572212542401530} 01523626 {VOICE INFO}xx

which is transmitted starting from the leftmost phase. (Again, a number, h, in this final sequence is to be interpreted as a phase of πh/4). This phase sequence must pass through an RC filter prior to modulating the transmitted RF signal.

Appendix G

Format and Usage of the System Data and Header Segments for VDL Mode 3 Operation

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The System Data segment of the M bursts and the Header segment of the V/D bursts is used for controlling access to the channel (Section 3.3.2.1), for link management functions (Section 3.3.2.3), for controlling voice operation (Section 3.3.5) and for acknowledging uplink data transfer. The formats for and usage of these burst segments is given in this appendix.

G.1 General Formatting

G.1.1 Unused Reserved (Spare) Bits

Any unused reserved (spare) bit fields which are not defined to a specific value shall be defaulted to value zero.

G.1.2 Bit Ordering

Bit fields in this appendix shall be encoded such that the most significant bit is in the lowest bit number position. For binary data listed in tables, the left-most bit shall be considered the most significant bit.

G.2 M Burst

G.2.1 Non-3T Configuration M Uplink System Data Segment (Generic Elements)

The non-3T configuration uplink System Data segment consists of 48 bits or 6 octets. The first three octets, including Message ID, System Configuration, Voice Signal, Aircraft ID (poll), Slot ID, Ground Station Code, and Squelch Window, are common for all uplink messages. The remaining 3 octets are assigned depending on the message type of the M uplink burst. Figure G-1 displays the non-3T configuration generic uplink System Data segment format.

	first bit trans-mitted	Bit Number						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Voice Signal		Aircraft ID (Poll)	
2	Aircraft ID (Poll) (cont.)				System Configuration			
3	Slot ID		Ground Station Code			Squelch Window		
4								
5		(Message Dependent)						
6								

Figure G-1. Non-3T Configuration Generic M Uplink System Data Segment

G.2.1.1 Message ID

The coding of the Message ID field is given in Table G-1. This field is used to aid the receiver in identifying the burst type.

Table G-1:~~.~~ M Burst Messages

	Message ID	**M Bursts**	**Section # of this Appendix**
Uplink	0000	Normal Message	2.2
	0001	Net Entry Response Message (no previous link)	2.3
	0010	Net Entry Response Message (previous link preserved)	2.3
	0011	Next Net Command Message	2.4
	0100	Recovery Message	2.5
	0101	Handoff Check Message	2.6
	0110	Terminate Net Message	2.14
	0111	Supported Options Message	2.15
Downlink	Identified by separate sync sequence	Net Entry Request Message	2.9
	1000*	Reservation Request Message	2.10
	1001*	Acknowledgement Message	2.11
	1010*	Leaving Net Message	2.12
	1011-1111*	Spare	
	1000**	4-slot configuration Poll Response	2.10
	1001**	Spare	
	1010**	3-slot configuration Poll Response	2.10
	1011**	Spare	
	1100**	3T configuration Poll Response	2.10
	1101**	Spare	
	1110**	Spare	
	1111**	Next Net ACK	2.13

* Identified by standard synchronization sequence defined in Section 3.3.1.3.2.1.2.

** Identified by special synchronization sequence for poll responses referenced in Section 3.3.1.3.2.1.2, and defined in Section 3.3.1.3.1.1.2.

	~~Message ID~~	~~M Bursts~~	~~Section # of this Appendix~~
~~Uplink~~	~~0000~~	~~Normal Message~~	~~2.2~~
	~~0001~~	~~Net Entry Response Message (no previous link)~~	~~2.3~~
	~~0010~~	~~Net Entry Response Message (previous link preserved)~~	~~2.3~~
	~~0011~~	~~Next Net Command Message~~	~~2.4~~
	~~0100~~	~~Recovery Message~~	~~2.5~~
	~~0101~~	~~Handoff Check Message~~	~~2.6~~
	~~0110-0111~~	~~Spare~~	
~~Downlink~~	~~Identified by separate sync sequence~~	~~Net Entry Request Message~~	~~2.9~~
	~~1000*~~	~~Reservation Request Message~~	~~2.10~~
	~~1001*~~	~~Acknowledgement Message~~	~~2.11~~
	~~1010*~~	~~Leaving Net Message~~	~~2.12~~
	~~1011-1111*~~	~~Spare~~	
	~~1000**~~	~~4-slot configuration Poll Response~~	~~2.10~~
	~~1001**~~	~~Spare~~	
	~~1010**~~	~~3-slot configuration Poll Response~~	~~2.10~~
	~~1011**~~	~~Spare~~	
	~~1100**~~	~~3T configuration Poll Response~~	~~2.10~~
	~~1101**~~	~~Spare~~	
	~~1110**~~	~~Spare~~	
	~~1111**~~	~~Next Net ACK~~	~~2.13~~

~~* Identified by standard synchronization sequence defined in Section 3.3.1.3.2.1.2.~~
~~** Identified by special synchronization sequence for poll responses defined in Section 3.3.1.3.2.1.2.~~

G.2.1.2 System Configuration

The system configuration is a 4 bit data field. The list of defined System Configurations is given in Table G-2 below.

Table G-2~~.~~: System Configuration Codes

Code	**System Configuration**

0000	4V
0001	3S
0010	3V1D
0011	2V2D
0100	3T
0101	3V
0110	2V1D
0111	2S1X
1000	1V3D
1001	1V2D
1010-1111	Spare

~~Code~~	~~System Configuration~~
~~0000~~	~~4V~~
~~0001~~	~~3S~~
~~0010~~	~~3V1D~~
~~0011~~	~~2V2D~~
~~0100~~	~~3T~~
~~0101~~	~~3V~~
~~0110~~	~~2V1D~~
~~0111~~	~~2S1X~~
~~1000-1111~~	~~Spare~~

G.2.1.3 Voice Signal

The Voice Signal field is used by the ground station to maintain a degree of control over the voice channel. The valid codes are listed in Table G-3 below.

Table G-3. Voice Signal Codes

Code	Description
00	Ground access (clears mobiles off)
01	Occupied
10	Voice channel idle
11	Spare

G.2.1.4 Aircraft ID (Poll)

The Aircraft ID is a 6 bit field used to uniquely identify aircraft of a given user group. It is assigned by the ground station as part of the net entry process. The valid Aircraft IDs are listed in Table G-4 below:

Table G-4:~~.~~ Aircraft ID Codes

Code	**Description**
0	Ground
1-60	Aircraft user
61	Discrete addressing not supported
62	~~Discrete addressing not supported (use alternative validity window)~~Spare
63	Broadcast

As part of the generic portion of the M uplink System Data segment, this field is used to poll a selected aircraft. When polled, an aircraft transmits an M downlink message in the next MAC cycle without contention.

G.2.1.5 Slot ID

The Slot ID indicates the slot the message is associated with in order to provide the VDL receiver with proper TDMA frame alignment. The valid codes are described in Table G-5 below.

Table G-5. Slot ID Codes

Code	Description
00	Slot A
01	Slot B
10	Slot C
11	Slot D

G.2.1.6 Ground Station Code

The Ground Station Code is a 3 bit field used to identify the ground station transmitting the burst. A check of this code by the receiver against the code obtained during Net Entry allows discrimination against transmissions from cochannel stations in other service volumes that could possibly be received due to anomalous propagation. Assignment of these codes to ground stations is a spectrum engineering matter.

G.2.1.7 Squelch Window

The Squelch Window provides a mechanism to suppress certain received voice messages as cochannel interference based on the time of arrival of the V/D (voice) bursts. The Squelch Window specifies the range, expressed in symbol periods, within which the first symbol of the synchronization sequence of a voice burst must occur. Voice bursts with the first symbol of the synchronization sequence arriving outside the Squelch Window shall be suppressed. The Squelch Window parameter n is equal to the numerical value of the 3-bit Squelch Window field. To find the Squelch Window range for a given Squelch Window code, substitute the value n in Table 3-92 and Table 3-93 for the corresponding system configurations, aircraft VDL timing states, and the message type of the incoming voice traffic.

G.2.2 Normal Message

The normal message shown in Figure G-2, is used to poll an aircraft and signal reservations. Two reservation response opportunities are included in a normal message. Each Reservation Response field consists of 12 bits.

Each Reservation Response field can signal the actual allocation of channel resources to a requesting aircraft.

	first bit transmitted	**Bit Number**						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Voice Signal		Aircraft ID (Poll)	
2	Aircraft ID (Poll) (cont.)				System Configuration			
3	Slot ID		Ground Station Code			Squelch Window		
4	Reservation Response #1							
5	Reservation Response #1 (cont.)				Reservation Response #2			
6	Reservation Response #2 (cont.)							

Figure G-2. M Uplink (Normal Message)

G.2.2.1 Reservation Response

Each Reservation Response field contains three subfields as follows:

- Group ID (2 bits): The Group ID is coded identically as the Slot ID (Section G.2.1.5). In this case it is used in conjunction with the Aircraft ID to uniquely identify each aircraft in all user groups on a frequency supported by the ground station.

  Note: *The Group ID and the Aircraft ID fields are collectively referred to as the Local User-ID.*

- Aircraft ID (6 bits): Section G.2.1.4 defines the valid codes. When the Reservation Response field is not used, the value of 0 shall be used in the Aircraft ID field.

- Reserved Slot (4 bits): This subfield indicates the slot for which V/D (data) burst access has been scheduled to begin. This subfield is binary coded as indicated below:

Table G-6~~.~~: Reserved Slot Subfield Encoding

Code	Description
0000	No Reservation Information
0001	RACK (UDR Supported)
0010	RACK (UDR Not Supported)
0011	Spare
0100	Data Reservation (start in even B-slot)
0101	Data Reservation (start in odd B-slot)
0110	Data Reservation (start in even B-slot, skip D)
0111	Data Reservation (start in odd B-slot, skip D)
1000	Data Reservation (start in even C-slot)
1001	Data Reservation (start in odd C-slot)
1010	Data Reservation (start in even C-slot, skip D)
1011	Data Reservation (start in odd C-slot, skip D)
1100	Data Reservation (start in even D-slot)
1101	Data Reservation (start in odd D-slot)
1110	Voice Reservation (start in even D-slot)
1111	Voice Reservation (start in odd D-slot)

~~Code~~	~~Description~~
~~0000~~	~~No Reservation Information~~
~~0001~~	~~RACK~~
~~0010~~	~~Spare~~
~~0011~~	~~Spare~~
~~0100~~	~~Data Reservation (start in even B-slot)~~
~~0101~~	~~Data Reservation (start in odd B-slot)~~
~~0110~~	~~Data Reservation (start in even B-slot, skip D)~~
~~0111~~	~~Data Reservation (start in odd B-slot, skip D)~~
~~1000~~	~~Data Reservation (start in even C-slot)~~
~~1001~~	~~Data Reservation (start in odd C-slot)~~
~~1010~~	~~Data Reservation (start in even C-slot, skip D)~~
~~1011~~	~~Data Reservation (start in odd C-slot, skip D)~~
~~1100~~	~~Data Reservation (start in even D-slot)~~
~~1101~~	~~Data Reservation (start in odd D-slot)~~
~~1110~~	~~Voice Reservation (start in even D-slot)~~
~~1111~~	~~Voice Reservation (start in odd D-slot)~~

~~*Note: For non-3T configurations, use only the codes with the third bit set to 0. For system configuration 2V2D, allowable values are 0000, 0001, 1000, 1001, 1100, and 1101. For system configuration 3V1D, allowable values are 0000, 0001, 1100, and 1101. For system configuration 2V1D, allowable values are 0000, 0001, 1000, and 1001.*~~

Note: For non-3T configurations, use only the codes with the third bit set to 0. For system configuration 2V2D, allowable values are 0000, 0001, 1000, 1001, 1100, and 1101. For system configuration 3V1D, allowable values are 0000, 0001, 1100, and 1101. For system configuration 2V1D, allowable values are 0000, 0001, 1000, and 10001. For configuration 1V3D the allowable values are 0000, 0001, 0100, 0101, 1000, 1001, 1100, and 1101. For configuration 1V2D the allowable values are 0000, 0001, 0100, 0101, 1000, and 1001.

G.2.3 Net Entry Response Message

This message type is used to acknowledge the Net Entry Request message and to assign the Local User ID to the requesting aircraft. This Local User ID is the combination of the Slot ID field and the Aircraft ID field. The aircraft ICAO address is attached to allow the receiver to validate the message. This message is shown in Figure G-3.

Note: Two separate Message IDs are used for this message. If the new ground station is unable to redirect the link from the previous ground station Message ID = 0001, "no previous link," is used. If the new ground station can support redirection of the link from the previous ground station Message ID = 0010, "previous link preserved" is used.

	first bit trans-mitted	Bit Number						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Voice Signal		Aircraft ID (Poll)	
2	Aircraft ID (Poll)				System Configuration			
3	Slot ID		Ground Station Code			Squelch Window		
4								
5		ICAO Aircraft Address						
6								

Figure G-3. M Uplink (Net Entry Response Message)

G.2.4 Next Net Command Message

The Next Net Command message shown in Figure G-4, is delivered by the ground station to a particular aircraft user to identify the slot and frequency of the next net connection.

G.2.4.1 Next Net

The Next Net field is 12 bits. It contains two subfields: Next Group ID (2 bits) and Frequency (10 bits). The Next Group ID field is located in bits 1 and 2 of octet 4 and is encoded the same as defined in Section G.2.2.1 when the Net Type field is set to 1 (TDMA). However, when the Net Type field is set to 0 (AM), the field shall be set as defined in Table G-7 below. For a frequency X in megahertz, the Frequency field is encoded as 40(X-112) with the most significant bit starting at bit 3 of octet 4.

Note: For 8.33 kHz channels that are not a multiple of a 25 kHz channel, the value of X used for encoding shall be that of the next lowest 25 kHz channel. The frequencies of these 8.33 kHz channels are uniquely identified by use of the Next Group ID field.

~~The Next Net field is 12 bits. It contains two subfields: Next Group ID (2 bits) and Frequency (10 bits). The Next Group ID field is the same as defined in Section G.2.2.1 when the Net Type field is set to 1 (TDMA). However, when the Net Type field is set to 0 (AM), the field shall be set as defined in Table G-7 below. For a frequency X in megahertz, the Frequency field is encoded as 40(X-112).~~

~~*Note: For 8.33 kHz channels that are not a multiple of a 25 kHz channel, the value of X used for encoding shall be that of the next lowest 25 kHz channel. The frequencies of these 8.33 kHz channels are uniquely identified by use of the Next Group ID field.*~~

Table G-7. Next Net Subfield Encoding when Net Type field set to 0 (AM)

Next Group ID Field	Description	Frequency
00	25 kHz	X
01	8.33 kHz	X
10	8.33 kHz	X+0.00833
11	8.33 kHz	X+0.01666

G.2.4.2 Local User ID

The Local User ID field consists of the Group ID and the Aircraft ID fields (see Section G.2.2.1).

G.2.4.3 Net Type

This field indicates whether the next net is a TDMA net or simply an AM frequency. A 0 indicates AM and a 1 indicates TDMA.

	first bit trans- mitted			Bit Number				
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Voice Signal		Aircraft ID (Poll)	
2	Aircraft ID (Poll) (cont.)				System Configuration			
3	Slot ID		Ground Station Code			Squelch Window		
4	Next Net							
5	Next Net (continue)				Net Type	Next Ground Station Code		
6	Local User ID							

Figure G-4. M Uplink (Next Net Command Message)

G.2.5 Recovery Message

This message is used to inform aircraft that the ground station is in the link recovery state. This message invokes recovery procedures in the aircraft LME as described in Section 3.3.2.3. This message is shown in Figure G-5.

	first bit trans- mitted			Bit Number				
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Voice Signal		Aircraft ID (Poll)	
2	Aircraft ID (Poll) (cont.)				System Configuration			
3	Slot ID		Ground Station Code			Squelch Window		
4	Reservation Response #1							
5	Reservation Response #1 (cont.)				Reservation Response #2			
6	Reservation Response #2 (cont.)							

Figure G-5. M Uplink (Recovery Message)

G.2.6 Handoff Check Message

The Handoff Check message, Figure G-6, is used only in System Configuration 3T in order to facilitate link management when the ground station is not supporting specific air traffic control sectors or user groups. The Handoff Check message contains information on proximate VDL ground stations to be scanned.

If more than four stations are adjacent to the station in question, the frequencies can be rotated every fifth MAC cycle (1.2 sec).

<table>
<tr><th></th><th>first bit trans-mitted</th><th colspan="7">Bit Number</th></tr>
<tr><th>Octet No.</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th></tr>
<tr><td>1</td><td colspan="4">Message ID</td><td colspan="3">Ground Station Code</td><td>Spare</td></tr>
<tr><td>2</td><td colspan="6">Ground Subnetwork Address</td><td colspan="2">Adjacent Frequency 1</td></tr>
<tr><td>3</td><td colspan="8">Adjacent Frequency 1 (cont.)</td></tr>
<tr><td>4</td><td colspan="2">Spare</td><td colspan="6">Adjacent Frequency 2</td></tr>
<tr><td>5</td><td colspan="4">Adjacent Frequency 2 (cont.)</td><td colspan="2">Spare</td><td colspan="2">Adjacent Frequency 3</td></tr>
<tr><td>6</td><td colspan="8">Adjacent Frequency 3 (cont.)</td></tr>
<tr><td>7</td><td colspan="2">Spare</td><td colspan="6">Adjacent Frequency 4</td></tr>
<tr><td>8</td><td colspan="5">Adjacent Frequency 4 (cont.)</td></tr>
</table>

Figure G-6. M Uplink (Handoff Check Message)

G.2.6.1 Ground Subnetwork Address

This field consists of the 6 bit ground subnetwork address of the GNI used by the ground station to communicate with the router. See Section 3.3.2.2.2.4.1 for more information.

G.2.6.2 Adjacent Frequency

Each Adjacent Frequency field consists of a 10 bit frequency for an adjacent net. The frequencies are numbered 1-4 to alert aircraft to the frequencies of four nets adjacent to the current radio 3T frequency net. Adjacent Frequency fields that are unused are set to all "1's."

> Note: *In order to support link management, all stations must be time synced in order that the Handoff Check message can be heard by all aircraft at the same point in the MAC cycle. This is accomplished by scanning to frequencies of adjacent ground stations during the established time (LBAC #12) of each MAC cycle.*

G.2.7 3T Configuration M Uplink System Data Segment (Generic Elements)

The 3T configuration uplink System Data segment consists of 192 bits or 24 octets. The fourth through the sixth semi-octets, including the System Configuration, Slot ID, Ground Station Code, and Squelch Window, are common to all uplink messages. Semi-octets 1 through 3 and 7 through 12 are used to control activities in User Group B. Semi-octets 1 through 3 control polling access for users in User Group B. Semi-octets 7 through 12 can be Net Entry Response messages, Next Net Command message, or Recovery message. Similarly, semi-octets 13 through 21 are devoted to User Group C; semi-octets 22 through 30 are devoted to User Group D. Figure G-7 displays the 3T configuration generic uplink System Data segment format.

		first bit trans-mitted	Bit Number						
Octet No.	**Semi-octet**	1	2	3	4	5	6	7	8
1	1, 2	Message ID (B)				Voice Signal (B)		Aircraft ID (Poll) (B)	
2	3, 4	Aircraft ID (Poll) (B) (cont.)				System Configuration			
3	5, 6	Slot ID		Ground Station Code			Squelch Window		
4	7, 8	Group B Message							
5	9, 10	Group B Message							
6	11, 12	Group B Message							
7	13, 14	Message ID (C)				Voice Signal (C)		Aircraft ID (Poll) (C)	
8	15, 16	Aircraft ID (Poll) (C) (cont.)				Group C Message			
9	17, 18	Group C Message							
10	19, 20	Group C Message							
11	21, 22	Group C Message				Message ID (D)			
12	23, 24	Voice Signal (D)		Aircraft ID (Poll) (D)					
13	25, 26	Group D Message							
14	27, 28	Group D Message							
15	29, 30	Group D Message							
16	31, 32	Reservation #1							
17	33, 34	Reservation #1 (cont.)				Reservation #2			
18	35, 36	Reservation #2 (cont.)							
19	37, 38	Reservation # 3							
20	39, 40	Reservation #3 (cont.)				Reservation #4			
21	41, 42	Reservation #4 (cont.)							
22	43, 44	Reservation #5							
23	45, 46	Reservation #5 (cont.)				Reservation #6			
24	47, 48	Reservation #6 (cont.)							

Figure G-7. 3T Configuration Generic M Uplink System Data Segment

G.2.8 M Downlink System Data Segment (Generic Elements)

The downlink System Data Segment consists of 24 bits or 3 octets. The Message ID, Ground Station Code, and Local User ID fields are common to all downlink messages except the Net Entry Request message. These fields are defined in Sections G.2.1.1, G.2.1.6, and G.2.2.1, respectively.

G.2.9 Net Entry Request Message

The Net Entry Request message consists of 24 bits containing only the ICAO address of the transmitting aircraft. To eliminate the need for a Message ID field and still allow the receiver to ascertain the message type, a separate synchronization sequence is used (See Section 3.3.1.3.2.1.2). This message is shown in Figure G-8.

	first bit trans-mitted	Bit Number						
Octet No.	1	2	3	4	5	6	7	8
1	ICAO Aircraft Address							
2	ICAO Aircraft Address							
3	ICAO Aircraft Address							

Figure G-8. M Downlink (Net Entry Request Message)

G.2.10 Poll Response and Reservation Request Messages

The Poll Response is used by the aircraft to respond to a poll contained in an M Uplink (Normal Message). The slot Reservation Request is used by the aircraft to request authorization to transmit data. The Poll Response and Reservation Request messages use the same message format as shown in Figure G-9.

	first bit trans-mitted	Bit Number						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Local User ID			
2	Local User ID (cont.)				Ground Station Code			Voice Request
3	Voice Request (cont.)	Number of Slots Requested				Spare	Data Priority	

Figure G-9. Poll Response and M Downlink (Reservation Request Message)

G.2.10.1 Number of Slots Requested

The Number of Slots Requested field is used to allow the station requesting the reservation to indicate the number of V/D (data) bursts required to complete the pending downlink data transmission. Up to 15 V/D (data) bursts can be requested.

G.2.10.2 Data Priority

This field consists of 2 bits. It defines the frame group priority level. Up to 4 different priorities can be specified.

> Note: *The 16 ATN message priorities are grouped into 4 VDL frame priority groups. VDL data frame priority is requested in a 2-bit data priority field shown in Figure G-9.*

G.2.10.3 Voice Request

The Voice Request field is a 2 bit field. The valid codes are listed as follows:

Code	**Description**
00	No request
01	Request routine access
10	Request priority access
11	Spare

Table G-8. Voice Request Field

The most significant bit shall be sent in octet 2 while the least significant bit shall be sent in octet 3, as shown in Figure G-9.

G.2.11 Acknowledgement Message

The Acknowledgement message shown in Figure G-10, is used by the aircraft to acknowledge a V/D (data) burst sequence.

	first bit transmitted	**Bit Number**						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Local User ID			
2	Local User ID (cont.)				Ground Station Code			Voice Request
3	Voice Request (cont.)	Spare			Spare			

Figure G-10. M Downlink (Acknowledgement Message)

G.2.12 Leaving Net Message

The Leaving Net message is shown in Figure G-11. It is used by the aircraft to notify the ground station that the aircraft is leaving the net.

	first bit trans-mitted	Bit Number						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Local User ID			
2	Local User ID (cont.)				Ground Station Code			Spare
3	Spare (cont.)						Spare	

Figure G-11. M Downlink (Leaving Net Message)

G.2.13 Next Net ACK message

The Next Net ACK message is shown in Figure G-12. It is used by the aircraft to acknowledge the receipt of the Next Net message to the ground station.

	first bit trans-mitted	Bit Number						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Local User ID			
2	Local User ID (cont.)				Ground Station Code			Spare
3	Spare (cont.)							

Figure G-12. M Downlink (Next Net ACK Message)

G.2.14 Terminate Net Message

The terminate net message shown in Figure G-12a, is used to terminate an aircraft link at the MAC sublayer. The first Golay word after the beacon information contains the Local Identifier of the aircraft whose net is being terminated, and four spare bits. One reservation response opportunity is also included in a terminate net message. The Reservation Response field consists of 12 bits. The Reservation Response field can signal the actual allocation of channel resources to a requesting aircraft.

	first bit transmitted	Bit Number						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Voice Signal		Aircraft ID (Poll)	
2	Aircraft ID (Poll) (cont.)				System Configuration			
3	Slot ID		Ground Station Code			Squelch Window		
4	Terminated Local ID							
5	Spare				Reservation Response			
6	Reservation Response (cont.)							

Figure G-12a: M Uplink (Terminate Net Message)

G.2.15 Supported Options Message

The Supported Options message shown in Figure G-12b, is used to indicate options that are supported by the current ground station. One Reservation Response field is included in this message, along with an Options field. Each Reservation Response field consists of 12 bits. The Reservation Response field can signal the actual allocation of channel resources to the entering aircraft. The Options field is a 12-bit field with each bit set to 1 to indicate a specific option is supported and 0 if not supported, as described in Table G-9. Reserved bits are set to 0.

	first bit transmitted	Bit Number						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID				Voice Signal		Aircraft ID (Poll)	
2	Aircraft ID (Poll) (cont.)				System Configuration			
3	Slot ID		Ground Station Code			Squelch Window		
4	Reservation Response							
5	Reservation Response (cont.)				Options			
6	Options (cont.)							

Figure G-12b: M Uplink (Supported Options Message)

Table G-9: Options field

Octet	Bit Number	Field
5	5	Urgent Downlink Request
5	6-8	reserved

6	1-8	reserved

G.3 V/D Burst

G.3.1 V/D (Voice) Burst Header Segment

The Header segment of the V/D (voice) burst is shown in Figure G-13.

	first bit trans- mitted			Bit Number				
Octet No.	1	2	3	4	5	6	7	8
1	Message ID = 0XX			Local User ID				
2	Local User ID (cont.)			EOM				

Figure G-13. V/D (Voice) Burst Header Segment

G.3.1.1 Message ID

Message ID	V/D Burst Type
000	Uplink voice
001	Downlink voice: TS1
010	Downlink voice: TS2
011	Downlink voice: TS3
100	Uplink data - Acknowledged
101	Downlink data - Acknowledged
110	Uplink data - Unacknowledged
111	Downlink data - Unacknowledged

G.3.1.2 EOM

This field is used to signal the last burst in a voice or data message. Binary 1 shall indicate the last burst.

G.3.2 V/D (Data) Burst Header Segment

The Header segment of the V/D (data) burst is shown in Figure G-14.

	first bit transmitted	Bit Number						
Octet No.	1	2	3	4	5	6	7	8
1	Message ID = 1XX			Ground Station Code			Segment Number	
2	Segment Number		Spare	EOM				

Figure G-14. V/D (Data) Burst Header Segment

G.3.2.1 Segment Number

This field is used to allow the receiver to reassemble the segments of the V/D (data) burst sequence into a DLPDU for transfer to the DLS sublayer.

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Appendix H

Random Number Generation Algorithm

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Certain functions of the radio system related to RA require the generation of a “random” number. For instance, in all configurations the radio normally must choose which slot to use for a Net Entry Request. To ensure that different radios generate different numbers, the algorithm for generating random numbers is based on the unique 24-bit ICAO address. Because it is possible that on some platforms there may be more than one radio using the same ICAO address, the algorithm also makes use of a radio ID to allow each radio on an aircraft to have an independent random number generator. One example of such a radio ID is the 2-bit Source/Destination Identifier (SDI) currently used in a multiple radio installation on some platforms to identify the left radio, the center radio, the right radio, and all radios (all call). The radio ID is set to 0 whenever there is only one radio on board a particular aircraft.

The algorithm generates a new 12-bit number at each access as follows. First, the 24-bit address is broken into 2 12-bit pieces ($a(0)$ and $a(1)$) so that

$$ICAOAddress = 4096 \cdot a(1) + a(0).$$

These are used to generate two sequences of numbers using the recursion relations

$$M(n) = (4093 \cdot M(n-1) + a(0) + 1) \bmod 4111$$

$$N(n) = ((4021 + SDI) \cdot N(n-1) + a(1) + 1) \bmod 4099$$

with $M(0) = N(0) = 0$. These are then combined to give a single random number

$$K(n) = (M(n) + N(n)) \bmod 4099.$$

This ensures that two radios will never choose the same pseudorandom number repeatedly.

This algorithm produces 2^{24} unique sequences (2^{26} if a 2-bit radio ID is included), each of which is nearly uniform in distribution. No two sequences have any long subsequences in common, no matter what their relative time offset might be. These sequences can be used to derive sequences of numbers drawn from a smaller alphabet. Suppose, for example, that a sequence of numbers between 0 and 8 (inclusive) must be generated for random access in configuration 2V2D. Such a number can be derived from $K(n)$ by invoking the formula

$$R(n) = Int\left(\frac{K(n)}{4099} \cdot 9\right)$$

where $Int(\ )$ means the integer part of the argument.

~~Certain functions of the radio system related to RA require the generation of a “random” number. For instance, in all configurations the radio normally must choose which slot to use for a Net Entry Request. To ensure that different radios generate different numbers, the algorithm for generating random numbers is based on the unique 24-bit ICAO address.~~

~~The algorithm generates a new 12-bit number at each access as follows. First, the 24-bit address is broken into 2 12-bit pieces ($a(0)$ and $a(1)$) so that~~

~~$ICAO\ Address = 4096 \cdot a(1) + a(0)$~~

~~These are used to generate two sequences of numbers using the recursion relations~~

~~$M(n) = (4093 \cdot M(n-1) + a(0) + 1) \bmod 4111$~~

~~$N(n) = (4021 \cdot N(n-1) + a(1) + 1) \bmod 4099$,~~

~~with $M(0) = N(0) = 0$. These are then combined to give a single random number~~

~~$K(n) = (M(n) + N(n)) \bmod 4099$.~~

~~This ensures that two radios will never choose the same pseudorandom number repeatedly.~~

~~This algorithm produces 2^{24} unique sequences, each of which is nearly uniform in distribution. No two sequences have any long subsequences in common, no matter what their relative time offset might be. These sequences can be used to derive sequences of numbers drawn from a smaller alphabet. Suppose, for example, that a sequence of numbers between 0 and 8 (inclusive) must be generated for random access in configuration 2V2D. Such a number can be derived from $K(n)$ by invoking the formula~~

~~$R(n) = Int\left(\frac{K(n)}{4099} \cdot 9\right)$~~

~~where $Int(\ )$ means the integer part of the argument.~~

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Appendix I

Random Access Downlink M Burst Selection Algorithms for Aircraft Radios

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The generic process for selecting an appropriate random access downlink M burst to transmit a Net Entry Request (E), a Reservation Request (R), and a Leaving Net (L) type messages shall be as described below. The process for selecting an appropriate downlink M burst for subsequent retransmission of a Net Entry message and a Reservation Request message shall also be as described below.

Step 1. Request for a RA downlink M burst arrives at MAC layer prior to LBACx in MAC cycle N.

Initial Transmission

Step 2. Aircraft radio shall choose a random integer, r, which obeys $0\#r\#R_n$, using algorithm of Appendix H. Rn shall be a MAC Service (or LME) System Parameter dependent on configuration and process type (n = E, R, or L), i.e., RE for Net Entry, RR for Reservation Request, and RL for Leaving Net.

Step 3. Aircraft radio shall skip r available RA opportunities and transmit in the next available RA downlink M burst, e.g., in LBACy in MAC cycle Z.

Step 4. For Net Entry and Reservation Request, the aircraft radio shall wait for Wn (n = E or R) MAC cycles, respectively, for appropriate reply from the ground station until LBACy in MAC cycle Z+Wn before attempting to retransmit the net entry or reservation request message. The parameter Wn shall be a MAC Service (or LME) System Parameter dependent on configuration and process type (n = E or R), i.e., WE for Net Entry and WR for Reservation Request. If a valid response is received on or before LBACy in MAC cycle Z+Wn the process shall be terminated.

Retransmission

Step 5. If a valid response is not received by LBACy in MAC cycle Z + Wn, where Z and Wn are defined in Step 4, the Net Entry or Reservation Request message shall be retransmitted by repeating the above procedures beginning in Step 2.

Notes:

1. *The available LBACs depend on process type (Net Entry, Reservation Request, or Leave Net) and configuration. LBACs scheduled for Poll Responses and downlink ACKs are removed from the lists. The initial list includes all downlink M burst LBACs available to the relevant net.*

2. *Steps 4 and 5 are not applicable to Leaving Net since a Leaving Net message requires no reply.*

   Failure to detect an uplink V/D (data) burst with an EOM indication may cause an aircraft VDL to transmit in a downlink RA M channel, which has been reserved for downlink ACK for another aircraft and can corrupt the downlink ACK transmission. Duplicate messages will occur as a result.

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Appendix J

ISO 8208 Compression Definition

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J.1 ISO 8208 Compressor Architecture.

The ISO 8208 compressor provides a connection oriented packet data service that supports the ATN ISO 8208 mobile SNDCF. The ISO 8208 compressor provides reliable sequenced delivery of packets in support of ATN mobile SNDCF compression procedures and additionally provides subnetwork compression of ISO 8208 packets for increased bandwidth utilization. The ISO 8208 compressor provides packet multiplexing to further increase subnetwork efficiency and provides error detection and recovery from dropped, missequenced or duplicate packets. The ISO 8208 compressor architecture consists of the following elements for both ground and aircraft systems:

- ISO 8208 DCE
- Internetworking (IW) functions
- XDCE (VDL Mode 3 Packet Layer Protocol)

The ISO 8208 compressor architecture is illustrated in Figure J.1-1. As indicated in Figure J.1-1, the Aircraft Network Interface (ANI) and Ground Network Interface (GNI) refer to the complete functionality required to interface to an ATN router, which implements the ATN ISO 8208 mobile SNDCF and DTE, to the VDL Mode 3 subnetwork. In the context of this appendix, ANI and GNI refer to this functionality when ISO 8208 compression is signaled. XNI is a general term that applies to function of both the ANI and GNI.

J.1.1 ISO 8208 Compression Formatting.

This appendix defines the ISO 8208 compression performed for ISO 8208 packets received from the local DCE for transfer over the VDL Mode 3 system that indicate the appropriate subnetwork compression. ISO 8208 compression shall be signaled by the Payload Identification octet, the 1st octet of user data in the Information frame of the Data link layer.

J.1.2 ISO 8208 Compression Header Definition.

ISO 8208 Compression header definition shall be defined as protocol type field 0000 (binary) indicating ISO 8208 protocol and Compression type field 0001 (binary) indicating VDL Mode 3 Packet Layer Protocol compression~~Mode 3 ISO 8208 Packet Layer Protocol compression~~.

J.2 Data Exchange Interfaces

J.2.1 DTE ISO 8208 Interface

J.2.1.1 General.

The interface between the XNI DCE and ATN Router DTE(s) shall conform to the ISO 8208 packet layer protocol. Accordingly, the XNI shall contain an ISO 8208 DCE.

Note: The ATN router contains a DTE.

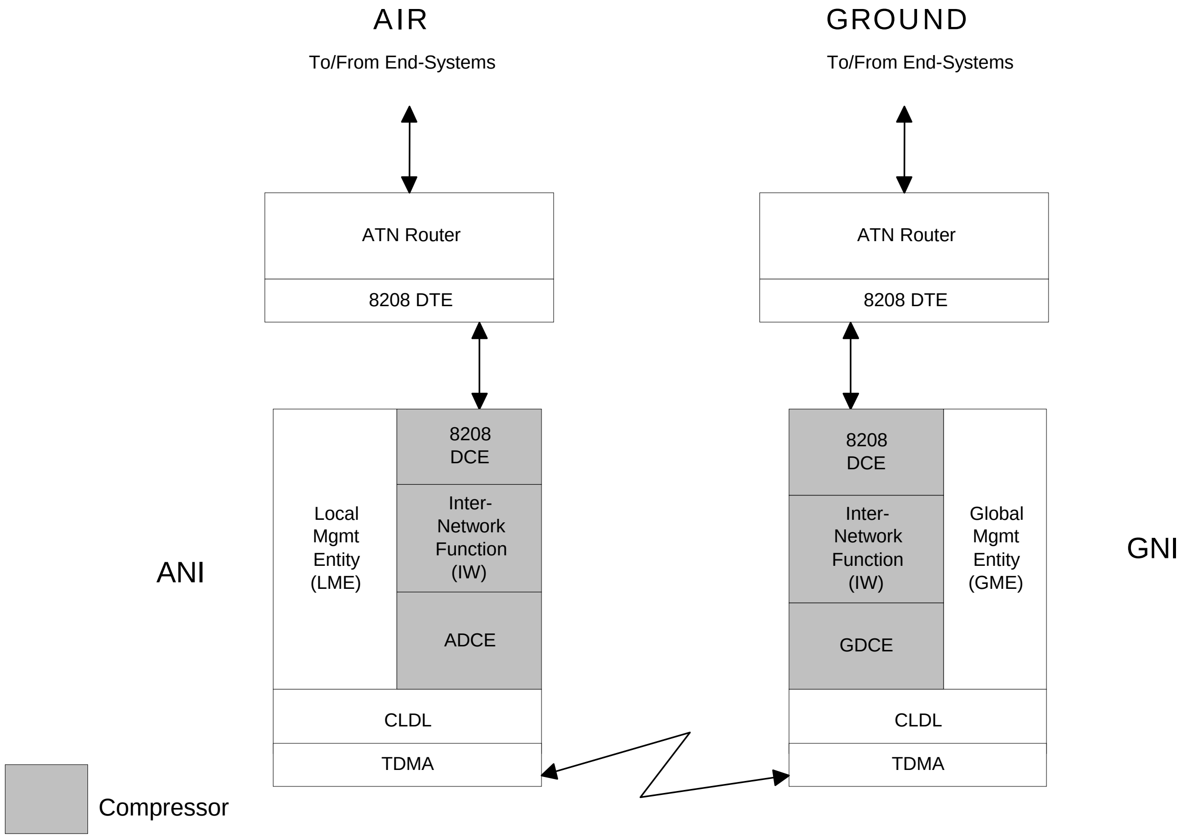
AIR
To/From End-Systems
GROUND
To/From End-Systems
ATN Router
8208 DTE
ATN Router
8208 DTE
ANI
Local Mgmt Entity (LME)
8208 DCE
Inter-Network Function (IW)
ADCE
8208 DCE
Inter-Network Function (IW)
GDCE
Global Mgmt Entity (GME)
GNI
CLDL
TDMA
CLDL
TDMA
Compressor

Figure J.1-1: ISO 8208 Compressor Architecture

J.2.2 DTE Address Requirements

J.2.2.1 Ground DTE Address

The ground DTE address shall have a total length of 3 Binary Coded Decimal (BCD) digits, as follows:

X_0 X_1 X_2 (X_0 shall be the most significant digit)

Ground DTE address shall be in the range of 0 through 255.

Note: Assignment of the DTE addresses shall be a local issue.

J.2.2.2 Mobile DTE Address.

The mobile DTE address shall have a total length of 10 BCD digits, as follows:

X_0 X_1 X_2 X_3 X_4 X_5 X_6 X_7 X_8 X_9 (X_0 shall be the most significant digit)

The digits X_0 to X_7 shall contain the ICAO 24 bit aircraft address coded in BCD. The digits X_8 X_9 received as XID parameter ADSA (Section J.10.1) shall identify a sub-address for a specific DTE on board an aircraft. This sub-address shall be in the range of 0 through 15. The following sub-address assignments shall be used:

00	ATN router
01 to 15	Unassigned

J.2.2.2.1 Illegal DTE Address

DTE addresses outside of the defined ranges or not conforming to the formats for the ground and mobile DTE addresses specified in Sections J.2.2.1 and J.2.2.2 shall be defined to be illegal DTE addresses. The detection of an illegal DTE address in a CALL REQUEST Packet shall lead to a rejection of the call.

J.3 Packet Layer Protocol Requirements of the DTE/DCE Interface

J.3.1 Capabilities

The interface between the DTE and the DCE shall conform to ISO 8208 with the following capabilities:

- Expedited Data Delivery, i.e. the use of INTERRUPT Packets with a User Data Field of up to 32 bytes.
- Priority with up to 2 levels
- Fast Select
- Fast Select with restricted response

Other ISO 8208 facilities and the D-bit and the Q-bit shall not be invoked for transfer over the VDL Mode 3 packet layer protocol.

J.3.2 Parameter Values

The timers and counter parameters for the DTE/DCE interface shall be a local matter.

J.4 DCE Operation

> Note: *The DCE process within the XNI acts as a peer process to the DTE. The DCE supports the operations of the DTE with the capabilities specified in Section J.4.1. The following requirements do not specify format definitions and flow control on the DTE/DCE interface. The specifications and definitions of ISO 8208 apply for these cases.*

J.4.1 State Transitions

The DCE shall operate as a state machine with the states as identified in Table J.4-1. Upon entering a state, the DCE shall perform the actions specified in Table J.6-1. If a state transition is specified, the actions taken shall be as specified in Tables J.11-1 through J.11-10.

READY AND RESTART STATES	r1 r2 r3
CALL SETUP AND CLEARING STATES	p1 p2 p3 p4 p5 p6 p7
DATA TRANSFER STATES	d1 d2 d3
INTERRUPT & CONTROL STATES	f1 f2 g1 g2 i1 i2 j1 j2

Table J.4-1: DCE Substate Hierarchy

Note: *States r1, p4, and d1 are states that are provided to the lower level of the DCE state hierarchy*

J.4.2 Disposition of Packets

J.4.2.1 Receipt From DTE.

Upon receipt of a packet from the DTE, the packet shall be forwarded or not forwarded to the XDCE (GDCE/ADCE) (via the internetworking function) according to the parenthetical instructions contained in Tables J.11-1 to J.11-6. If no parenthetical instruction is listed or if the parenthetical instruction indicates "do not forward," the packet shall be discarded.

J.4.2.2 Receipt From XDCE

Upon receipt of a packet from the XDCE (via the internetworking function), the packet shall be forwarded or not forwarded to the DTE according to the parenthetical instructions contained in Tables J.11-7 to J.11-10. If no parenthetical instruction is listed or if the parenthetical instruction indicates “do not forward,” the packet shall be discarded.

J.5 VDL Mode 3 Packet Layer Processing

J.5.1 General Requirements

J.5.1.1 Channel Number Pools

J.5.1.1.1 XNI Channel Pool

The XNI shall maintain several SVC channel number pools; the DCE/DTE (ISO 8208) interface uses one set. Its organization, structure and use shall be as defined in the ISO 8208 standard. The other channel pools shall be used on the ADCE/GDCE interface.

J.5.1.1.2 GNI Channel Pool

The GNI shall manage a pool of temporary channel numbers in the range of 1 to 3, for each ground DTE/ANI pair. CALL REQUESTs generated by the GNI shall contain the ground DTE address and a temporary channel number allocated from the pool of that ground DTE. The GNI shall not reuse a temporary channel allocated to an SVC that is still in the Call Request state. The ANI shall use the ground DTE address to distinguish the temporary channels numbers used by the various ground DTEs. If a CALL REQUEST Packet is received from a GNI with a temporary channel number that is the same as one used in a previous request from the same ground DTE (i.e., the aircraft DTE has yet to accept the call) then the latest request shall be discarded by the ANI.

Notes:

1. The use of temporary channel numbers allows the GNI to have up to 3 CALL REQUESTs in progress at the same time for a particular DTE and ANI combination. It also allows the GNI or ANI to clear a channel before the assigned channel number is known.

2: The ANI may be in contact with multiple ground DTEs at any one time. All the ground DTEs use temporary channel numbers ranging from 1 to 3.

J.5.1.1.3 ANI Channel Number

The ANI shall assign a permanent channel number (in the range of 0 to 15) to all SVCs and shall inform the GNI of the assigned number by including it in the CALL REQUEST by ANI or CALL ACCEPT by ANI Packets. The temporary channel number shall be included in the CALL ACCEPT by ANI together with the permanent channel number in order to define the association of these channel numbers. The ANI shall continue to associate a temporary channel with a permanent channel of an SVC until a CALL REQUEST from the same ground DTE is received that contains the same temporary channel number. A temporary channel number of zero in the CLEAR REQUEST by ANI, CLEAR REQUEST by GNI, or the CLEAR CONFIRMATION by ANI Packet shall indicate that the permanent channel number is to be used. A non-zero temporary channel number in these packets shall indicate that the temporary channel number shall be used and the permanent channel number shall be ignored.

J.5.1.1.4 DTE/DCE Channel Number

The channel number used by the DTE/DCE interface and that used by the ADCE/GDCE interface shall be assigned independently. The Internetworking process shall maintain an association table between the DTE/DCE and the ADCE/GDCE channel numbers.

J.5.1.2 Receive Ready and Receive Not Ready Conditions

The ISO 8208 interface and the ADCE/GDCE interface management procedures shall be independent operations since each system must be able to respond to separate receive ready and receive not ready indications.

J.5.1.3 Processing of M-Bit Sequences

Note: M-bit processing is used for the orderly sequencing of reformatted DATA Packets.

J.5.1.3.1 M-Bit Processing

Note: The packet size used on the DTE/DCE interface can be different from that used on the ADCE/GDCE interface.

J.5.1.3.1.1 Reformatted Data Packets

M-bit processing shall be used when DATA Packets are reformatted. M-bit processing shall be conducted per the specifications contained in the ISO 8208 standard. The M-bit sequence processing shall apply on a per channel basis. The M-bit set to ONE shall indicate that a User Data Field continues in the subsequent DATA Packet.

J.5.1.3.1.2 Combining Packets

If the packet size for the XDCE interface is larger than that used on the DTE/DCE interface, packets shall be combined to the extent possible as dictated by the M-bit, when transmitting a VDL Mode 3 DATA Packet. If the packet size is smaller on the XDCE interface than that defined on the DTE/DCE interface, packets shall be fragmented to fit into the smaller VDL Mode 3 packet using M-bit assembly.

J.5.1.3.1.3 Filled and More Packets

A packet shall be combined with subsequent packets if the packet is filled and more packets exist in the M-bit sequence (M-bit = ONE). A packet smaller than the maximum packet size defined for this SVC (partial packet) shall only be allowed when the M-bit indicates the end of an M-bit sequence. A received packet smaller than the maximum packet size with M-bit equal to ONE shall cause a reset to be generated as specified in ISO 8208.

J.5.1.3.1.4 Recommendation

In order to decrease the delivery delay, reformatting should be performed on the partial receipt of an M-bit sequence, rather than delay reformatting until the complete M-bit sequence is received.

J.5.2 Internetworking Process

The internetworking process is divided into two subprocesses: uplink formatting and downlink formatting. For the ANI, the uplink process shall reformat VDL Mode 3 PLP packets into ISO 8208 packets and the downlink process shall reformat ISO 8208 packets into VDL Mode 3 PLP packets. For the GNI, the uplink process shall reformat ISO 8208 packets into VDL Mode 3 PLP packets and the downlink process shall reformat VDL Mode 3 PLP packets into ISO 8208 packets.

J.5.2.1 CALL REQUEST by ANI

J.5.2.1.1 Translation into VDL Mode 3 Packets

J.5.2.1.1.1 General

Reception by the ANI Internetworking Process of an ISO 8208 CALL REQUEST Packet from the local DCE shall result in the generation of a corresponding VDL Mode 3 CALL REQUEST by the ANI Packet as specified in Table J.5-1.

	MSB			**Bit Number**				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	P	FILL	SN					
3	CH				AM			
4	AG							
5	FS	FILL						
6 + n	FD_v							

Table J.5-1: VDL Mode 3 Call Request Packet

Note: FDv is fast select user data, which is defined in Section J.5.2.1.13.

In formatting the VDL Mode 3 packet the information shall be derived as follows.

J.5.2.1.1.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.2.1.1.3 VDL Supervisory Packet (VSP) Packet Type (VP)

This field shall be set to 1.

Note: VSP is a one bit field in Octet 1 of the 8208 compressor packets. When set to a value of 1, this indicates that the packet is part of the 8208 Packet Level Protocol compressor set. It allows for future expandibility of the 8208 compressor for different packet types.

J.5.2.1.1.4 Supervisory Packet (SP)

This field shall be set to 1.

J.5.2.1.1.5 Supervisory Type (ST)

This field shall be set to 0.

J.5.2.1.1.6 Priority (P)

This field shall be set to 0 for a low priority SVC and to 1 for a high priority SVC. The value for this packet shall be obtained from the Priority Facility of the ISO 8208 Packet. This field shall be set to 0 if the ISO 8208 packet does not contain the Priority Facility or if a priority other than 0 or 1 is specified.

J.5.2.1.1.7 Sequence Number (SN)

For a particular SVC, each packet shall be numbered.

J.5.2.1.1.8 Channel Number (CH)

The channel number shall be chosen from the pool of SVC channel numbers available to the ANI. The pool shall consist of 16 values from 0 to 15. The highest available channel number shall be chosen from the pool. An available channel shall be defined as one in state p1. The correspondence between the channel number used by the VDL Mode 3 subnetwork and the number used by the DTE/DCE interface shall be maintained while the channel is active.

J.5.2.1.1.9 Address, Mobile (AM)

This address shall be the mobile DTE sub-address in the range of 0 to 15. The address value shall be extracted from the 2 least significant BCD digits of the calling DTE address contained in the ISO 8208 packet and be converted to binary representation.

J.5.2.1.1.10 Address, Ground (AG)

This address shall be the ground DTE address in the range of 0 to 255. The address is obtained as part of the link initialization procedure as defined in Section J.10.2.

J.5.2.1.1.11 Fill Field

The Fill Field shall be used to align subsequent data fields on byte boundaries.

Note: The fill field is used to pad bytes to remain octet aligned. Fill fields shall take on a value of "0".

J.5.2.1.1.12 Fast Select Field (FS)

A value of zero shall indicate that the packet does not contain the Fast Select data and the Fill and FD Fields are not present. A value of one or two shall indicate that the packet contains Fast Select data and the Fill and FD Fields are present. A value of one indicates normal Fast Select operation. A value of two indicates Fast Select with restricted response. An FS value of three is undefined.

J.5.2.1.1.13 Fast Select User Data (FD)

This field shall only be present if the FS Field is set to the value of ONE. The Fast Select User Data Field shall be transferred from the ISO 8208 packet to the VDL Mode 3 packet.

J.5.2.1.2 Translation into ISO 8208 Packets

J.5.2.1.2.1 General

Reception by the GNI internetworking process of a VDL Mode 3 CALL REQUEST by ADLP Packet from the GDCE shall result in the generation of a corresponding ISO 8208 CALL REQUEST Packet to the local DCE. The translation from the VDL Mode 3 packet to the ISO 8208 packet shall be the reverse of the processing specified in Section J.5.2.1.1 with the exceptions as specified in the following paragraph.

J.5.2.1.2.2 Called DTE, Calling DTE Address and Length Fields

The calling DTE address shall be composed of the 24-bit ICAO address and the value contained in the AM Field of the VDL Mode 3 packet, each converted to BCD. The called DTE address shall be the ground DTE address contained in the AG Field of the VDL Mode 3 packet, converted to BCD. The Length field shall be as defined in ISO 8208.

J.5.2.2 CALL REQUEST by GNI

J.5.2.2.1 Translation into VDL Mode 3 Packets

J.5.2.2.1.1 General

Reception by the GNI internetworking process of an ISO 8208 CALL REQUEST Packet from the local DCE shall result in the generation of corresponding VDL Mode 3 CALL REQUEST by GNI Packet(s) as specified in Table J.5-2.

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	MSB			Bit Number				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	P	FILL	SN					
3	FILL		TC		AM			
4	AG							
5	FS		FILL					
6 + n	FD_v							

Table J.5-2: VDL Mode 3 Call REQUEST Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Section J.5.2.1.

J.5.2.2.1.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.2.2.1.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.2.2.1.4 Supervisory Packet (SP)

This field shall be set to 1.

J.5.2.2.1.5 Supervisory Type (ST)

This field shall be set to 0.

J.5.2.2.1.6 Temporary Channel Number field (TC)

This field shall be used to distinguish multiple call requests from a GNI. The ANI Internetworking Process, upon receipt of a temporary channel number, shall assign a channel number from those presently in the Ready State, p1.

J.5.2.2.1.7 Address, Ground (AG)

This address shall be the ground DTE address in the range of 0 to 255. The address shall be extracted from the 3-digit BCD calling DTE address contained in the ISO 8208 packet and be converted to binary representation.

J.5.2.2.1.8 Address, Mobile (AM)

This address shall be the mobile DTE sub address in the range of 0 to 15. The address shall be extracted from the 2 least significant BCD digits of the called DTE address contained in the ISO 8208 packet and be converted to binary representation.

J.5.2.2.2 Translation into ISO 8208 Packets

J.5.2.2.2.1 General

Reception by the ANI Internetworking Process of a VDL Mode 3 CALL REQUEST by GNI Packet from the ADCE shall result in the generation of a corresponding ISO 8208 CALL REQUEST Packet to the local DCE. The translation from the VDL Mode 3 packet to the ISO 8208 packet shall be the reverse of the processing defined in Section J.5.2.2.1 with the exceptions as specified in the following paragraph.

J.5.2.2.2.2 Called DTE, Calling DTE Address and Lengths Fields

The called DTE address shall be composed of the ICAO 24-bit aircraft address and the value contained in the AM Field of the VDL Mode 3 packet, each converted to BCD. The calling DTE address shall be the ground DTE address contained in the AG Field of the VDL Mode 3 packet, converted to BCD. The Length Field shall be as defined in ISO 8208.

J.5.2.3 CALL ACCEPT by ANI

J.5.2.3.1 Translation into VDL Mode 3 Packets

J.5.2.3.1.1 General

Reception by the ANI Internetworking process of an ISO 8208 CALL ACCEPT Packet from the local DCE shall result in the generation of corresponding VDL Mode 3 CALL ACCEPT by ANI Packet as specified in Table J.5-3.

	MSB			**Bit Number**				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST			FILL
2	TC		SN					
3	CH				AM			
4	AG							
5 + n	FD_v							

Table J.5-3: VDL Mode 3 Call ACCEPT Packet

Fields shown in the packet format and not specified in the following sections shall be set as specified in Section J.5.2.1.

J.5.2.3.1.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.2.3.1.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.2.3.1.4 Supervisory Packet (SP)

This field shall be set to 1.

J.5.2.3.1.5 Supervisory Type (ST)

This field shall be set to 1.

J.5.2.3.1.6 Temporary Channel Number (TC)

The TC value in the originating CALL REQUEST by GNI Packet shall be returned to the GNI along with the channel number (CH) assigned by the ANI.

J.5.2.3.1.7 Channel Number (CH)

The CH field shall be set equal to the channel number assigned by the ANI as determined during the CALL REQUEST procedures for the VDL Mode 3 connection.

J.5.2.3.1.8 Address, Mobile and Address, Ground

The AM and AG values in the originating CALL REQUEST by GNI Packet shall be returned in these fields. When present, DTE addresses in the ISO 8208 CALL ACCEPT Packet shall be ignored.

J.5.2.3.2 Translation into ISO 8208 Packets

J.5.2.3.2.1 General

Reception by the GNI Internetworking process of a VDL Mode 3 CALL ACCEPT by ANI Packet from the GDCE shall result in the generation of a corresponding ISO 8208 CALL ACCEPT Packet to the local DCE. The translation from the VDL Mode 3 packet to the ISO 8208 packet shall be the reverse of the processing defined in the following paragraph.

J.5.2.3.2.2 Called DTE, Calling DTE Address and Length Fields

The called DTE address shall be composed of the 24-bit ICAO aircraft address and the value contained in the AM Field of the VDL Mode 3 packet, each

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converted to BCD. The calling DTE address shall be the ground DTE address contained in the AG Field of the VDL Mode 3 packet, converted to BCD. The length field shall be as defined in ISO 8208.

J.5.2.4 CALL ACCEPT by GNI

J.5.2.4.1 Translation into VDL Mode 3 Packets

J.5.2.4.1.1 General

Reception by the GNI Internetworking Process of an ISO 8208 CALL ACCEPT Packet from the local DCE shall result in the generation of a corresponding VDL Mode 3 CALL ACCEPT by GNI Packet as specified in Table J.5-4.

	MSB				**Bit Number**			LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	FILL		SN					
3	CH				AM			
4	AG							
5 + n	FD_v							

Table J.5-4: VDL Mode 3 CALL ACCEPT Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Section J.5.2.1.

J.5.2.4.1.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.2.4.1.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.2.4.1.4 Supervisory Packet (SP)

This field shall be set to 1.

J.5.2.4.1.5 Supervisory Type (ST)

This field shall be set to 1.

J.5.2.4.1.6 Address, Mobile and Address, Ground

The AM and AG values in the originating CALL REQUEST by ANI Packet shall be returned in these fields. When present, DTE addresses in the ISO 8208 CALL ACCEPT Packet shall be ignored.

J.5.2.4.2 Translation into ISO 8208 Packets

J.5.2.4.2.1 General

Reception by the ANI Internetworking Process of a VDL Mode 3 CALL ACCEPT by GNI Packet from the ADCE shall result in the generation of a corresponding ISO 8208 CALL ACCEPT Packet to the local DCE. The translation from the VDL Mode 3 packet to the ISO 8208 packet shall be the reverse of the processing defined in Section J.5.2.4.1 with the exceptions as specified in the following paragraph.

J.5.2.4.2.2 Called DTE, Calling DTE Address and Length Fields

The calling DTE address shall be composed of the 24-bit ICAO aircraft address and the value contained in the AM Field of the VDL Mode 3 packet, each converted to BCD. The called DTE address shall be the ground DTE address contained in the AG Field of the VDL Mode 3 packet, converted to BCD. The length field shall be as defined in ISO 8208.

J.5.2.5 CLEAR REQUEST by ANI

J.5.2.5.1 Translation into VDL Mode 3 Packets

J.5.2.5.1.1 General

Reception by the ANI Internetworking Process of an ISO 8208 CLEAR REQUEST Packet from the local DCE shall result in the generation of a corresponding VDL Mode 3 CLEAR REQUEST by ANI Packet as specified in Table J.5-5.

	MSB			Bit Number				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	TC		SN					
3	CH				AM			
4	AG							
5	CC							
6	DC							
7 + n	FD_v							

Table J.5-5: VDL Mode 3 CLEAR REQUEST Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Sections J.5.2.1 and J.5.2.2.

J.5.2.5.1.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.2.5.1.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.2.5.1.4 Supervisory Packet (SP)

This field shall be set to 1.

J.5.2.5.1.5 Supervisory Type (ST)

This field shall be set to 2.

J.5.2.5.1.6 Address, Ground or Address, Mobile

The AG and AM values in the originating CALL REQUEST by ANI or CALL REQUEST by GNI packets shall be returned in these fields. When present, DTE addresses in the ISO 8208 CLEAR REQUEST Packet shall be ignored.

J.5.2.5.1.7 Clearing Cause (CC) and Diagnostic Code (DC) Fields

These fields shall be transferred without modification from the ISO 8208 packet to the VDL Mode 3 packet when the DTE has initiated the clear procedure. If the XNI has initiated the clear procedure, the Clearing Cause Field shall be set to "Out of Order" and the Diagnostic field shall be as defined in the state tables for the DCE and XDCE. The coding and definition of these fields shall be as specified in ISO 8208.

J.5.2.5.2 Translation into ISO 8208 Packets

J.5.2.5.2.1 General

Reception by the GNI Internetworking Process of a VDL Mode 3 CLEAR REQUEST by ANI Packet from the local GDCE shall result in the generation of a corresponding ISO 8208 CLEAR REQUEST Packet to the local DCE. The translation from the VDL Mode 3 packet to the ISO 8208 packet shall be the reverse of the processing defined in Section J.5.2.5.1.

J.5.2.5.2.2 Called DTE, Calling DTE and Length Fields

These fields shall be omitted in the ISO 8208 CLEAR REQUEST Packet.

J.5.2.6 CLEAR REQUEST by GNI

J.5.2.6.1 Translation into VDL Mode 3 Packets

J.5.2.6.1.1 General

Reception by the GNI internetworking process of an ISO 8208 CLEAR REQUEST Packet from the local DCE shall result in the generation of a corresponding VDL Mode 3 CLEAR REQUEST by GNI Packet as specified in Table J.5-6.

	MSB			**Bit Number**				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	TC		SN					
3	CH				AM			
4	AG							
5	CC							
6	DC							
7 + n	FD_v							

Table J.5-6: VDL Mode 3 CLEAR REQUEST Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Sections J.5.2.1 and J.5.2.2.

J.5.2.6.1.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.2.6.1.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.2.6.1.4 Supervisory Packet (SP)

This field shall be set to 1.

J.5.2.6.1.5 Supervisory Type (ST)

This field shall be set to 2.

J.5.2.6.2 Translation into ISO 8208 Packets

J.5.2.6.2.1 General

Reception by the ANI Intenetworking Process of a VDL Mode 3 CLEAR REQUEST by GNI Packet from the local ADCE shall result in the generation of a corresponding ISO 8208 CLEAR REQUEST Packet to the local DCE. The translation from the VDL Mode 3 packet to the ISO 8208 packet shall be the reverse of processing defined in Section J.5.2.6.1.

J.5.2.6.2.2 Called DTE, Calling DTE and length Fields

These fields shall be omitted in the ISO 8208 CLEAR REQUEST Packet.

J.5.2.7 DATA Packet

J.5.2.7.1 Translation into VDL Mode 3 Packets

J.5.2.7.1.1 General

Reception by the XNI internetworking process of ISO 8208 DATA Packet(s) from the local DCE shall result in the generation of corresponding VDL Mode 3 DATA Packet(s) as specified in Table J.5-7.

	MSB			**Bit Number**				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	M	SN					
2	PS				PR			
3	CH				FILL			
4 + n	UD$_v$							

Table J.5-7: VDL Mode 3 DATA Packet

J.5.2.7.1.2 Data Packet Type (DP)

This field shall be set to 1.

J.5.2.7.1.3 M Field (M)

A value of ONE shall indicate that the packet is part of an M-bit sequence with more packets in the sequence to follow. A value of ZERO shall indicate that the sequence ends with this packet. The appropriate value shall be placed in the M-bit Field of the VDL Mode 3 Packet.

J.5.2.7.1.4 Sequence Number (SN)

The Sequence number Field shall be set as specified in Section J.5.2.1.1.7.

J.5.2.7.1.5 Packet Send Sequence Number (PS)

The Packet Send Sequence Number Field shall be set as specified in Section J.6.4.4.

J.5.2.7.1.6 Packet Receive Sequence Number (PR)

The Packet Receive Sequence Number Field shall be set as specified in Section J.6.4.4.

J.5.2.7.1.7 Channel number (CH)

The Channel Number Field shall contain the VDL Mode 3 channel number that corresponds to the incoming ISO 8208 DATA Packet channel number.

J.5.2.7.1.8 Fill (Fill:4)

This field shall be set as specified in Section J.5.2.1.1.11.

J.5.2.7.1.9 User Data (UD)

The user data shall be transferred from the ISO 8208 packet to the VDL Mode 3 packet utilizing the M-bit packet assembly processing as required.

J.5.2.7.2 Translation into ISO 8208 Packets

Reception by the XNI Internetworking Process of VDL Mode 3 DATA Packets from the local XDCE shall result in the generation of corresponding ISO 8208 DATA Packet(s) to the local DCE. The translation from VDL Mode 3 packet(s) to the ISO 8208 packet(s) shall be the reverse of the processing defined in Section J.5.2.7.1.

J.5.2.8 INTERRUPT

J.5.2.8.1 Translation into VDL Mode 3 Packets

J.5.2.8.1.1 General

Reception by the XNI Internetworking Process of an ISO 8208 INTERRUPT Packet from the local DCE shall result in the generation of a corresponding VDL Mode 3 INTERRUPT Packet as specified in Table J.5-8.

	MSB				**Bit Number**			LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	FILL		SN					
3	CH				FILL			
4+n	UD_v							

Table J.5-8: VDL Mode 3 INTERRUPT Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Section J.5.2.1.

J.5.2.8.1.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.2.8.1.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.2.8.1.4 Supervisory Packet (SP)

This field shall be set to 3.

J.5.2.8.1.5 Supervisory Type (ST)

This field shall be set to 1.

J.5.2.8.1.6 User Data (UD)

The user data shall be transferred from the ISO 8208 packet to the VDL Mode 3 packet.

J.5.2.8.2 Translation into ISO 8208 Packets

Reception by the XNI Internetworking process of a VDL Mode 3 INTERRUPT Packet from the local XDCE shall result in the generation of a corresponding ISO 8208 INTERRUPT Packet to the local DCE. The translation from the VDL Mode 3 packet to the ISO 8208 packet shall be the reverse of the processing defined in Section J.5.2.8.1.

J.5.2.9 INTERRUPT CONFIRMATION

J.5.2.9.1 Translation into VDL Mode 3 Packets

J.5.2.9.1.1 General

Reception by the XNI Internetworking Process of an ISO 8208 INTERRUPT CONFIRMATION Packet from the local DCE shall result in the generation of a corresponding VDL Mode 3 INTERRUPT CONFIRMATION Packet as specified in Table J.5-9.

	MSB			**Bit Number**				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		SS	
2	FILL		SN					
3	CH				FILL			

Table J.5-9: VDL Mode 3 INTERRUPT CONFIRMATION Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Section J.5.2.1.

J.5.2.9.1.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.2.9.1.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.2.9.1.4 Supervisory Packet (SP)

This field shall be set to 3.

J.5.2.9.1.5 Supervisory Type (ST)

This field shall be set to 3.

J.5.2.9.1.6 Supervisory Subset (SS)

This field shall be set to 2.

J.5.2.9.2 Translation into ISO 8208 Packets

Reception by the XNI Internetworking process of a VDL Mode 3 INTERRUPT CONFIRMATION Packet from the local XDCE shall result in the generation of a corresponding ISO 8208 INTERRUPT CONFIRMATION Packet to the local DCE. The translation from the VDL Mode 3 packet to the ISO 8208 packet shall be the reverse of the processing defined in Section J.5.2.9.1.

J.5.2.10 RESET REQUEST

J.5.2.10.1 Translation into VDL Mode 3 Packets

J.5.2.10.1.1 General

Reception by the XNI Internetworking Process of an ISO 8208 RESET REQUEST Packet from the local DCE shall result in the generation of a corresponding VDL Mode 3 RESET REQUEST Packet as specified in Table J.5-10.

	MSB			**Bit Number**				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	FILL		SN					
3	CH				FILL			
4	RC							
5	DC							

Table J.5-10: VDL Mode 3 RESET REQUEST Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Section J.5.2.1.

J.5.2.10.1.2 Data Packet Type (DP)

This field shall be set to 0

J.5.2.10.1.3 VSP Packet Type (VP)

This field shall be set to 1

J.5.2.10.1.4 Supervisory Packet (SP)

This field shall be set to 2.

J.5.2.10.1.5 Supervisory Type (ST)

This field shall be set to 2.

J.5.2.10.1.6 Reset Cause Code (RC) and Diagnostic Code (DC)

The Reset Cause and Diagnostic Codes used in the VDL Mode 3 RESET REQUEST Packet shall be as specified in the ISO 8208 packet when the reset procedure is initiated by the DTE. If the reset procedure originates with the DCE, the DCE state tables specify the Diagnostic Fields coding. In this case, bit 8 of the Reset Cause field shall be set to 0.

J.5.2.10.2 Translation into ISO 8208 Packets

Reception by the XNI Internetworking Process of a VDL Mode 3 RESET REQUEST Packet from the local XDCE shall result in the generation of a corresponding ISO 8208 RESET REQUEST Packet to the local DCE. The translation from the VDL Mode 3 packet to the ISO 8208 packet shall be the reverse of the processing defined in Section J.5.2.10.1.

J.5.2.11 ISO 8208 RESTART REQUEST to VDL Mode 3 CLEAR REQUEST

The receipt of an ISO 8208 RESTART REQUEST from the local DCE shall result in the internetworking function generating a VDL Mode 3 CLEAR REQUEST by ANI or VDL Mode 3 CLEAR REQUEST by GNI for all SVCs associated with the requesting DTE. The fields of the CLEAR REQUEST Packets shall be set as specified in Sections J.5.2.5 and J.5.2.6.

> Note: *There are no restart states in the VDL Mode 3 packet layer protocol.*

J.5.3 Packets Local to the VDL Mode 3 Subnetwork

Packets defined in this section do not result in the generation of an ISO 8208 packet.

J.5.3.1 VDL Mode 3 RECEIVE READY

J.5.3.1.1 General

The VDL Mode 3 RECEIVE READY Packet arriving from the XNI is not related to the control of the DTE/DCE interface and shall not cause the generation of an ISO 8208 packet. The format of this packet shall be as specified in Table J.5-11.

	MSB				**Bit Number**			LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	FILL		SN					
3	CH				PR			

Table J.5-11: VDL Mode 3 RECEIVE READY Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Section J.5.2.1. The packet shall be processed as specified in Section J.6.5.

J.5.3.1.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.3.1.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.3.1.4 Supervisory Packet (SP)

This field shall be set to 2.

J.5.3.1.5 Supervisory Type (ST)

This field shall be set to 0.

J.5.3.1.6 Packet Receive Sequence Number (PR)

This field shall be set as specified in Section J.6.4.4.

J.5.3.2 VDL Mode 3 RECEIVE NOT READY

J.5.3.2.1 General

The VDL Mode 3 RECEIVE NOT READY Packet arriving from the XNI is not related to the control of the DTE/DCE interface and shall not cause the generation of an ISO 8208 packet. The format of this packet shall be as specified in Table J.5-12.

<table>
<tr><td></td><td>MSB</td><td colspan="6">Bit Number</td><td>LSB</td></tr>
<tr><td>Octet</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td>1</td><td>DP</td><td>VP</td><td colspan="2">SP</td><td colspan="2">ST</td><td colspan="2">FILL</td></tr>
<tr><td>2</td><td colspan="2">FILL</td><td colspan="6">SN</td></tr>
<tr><td>3</td><td colspan="4">CH</td><td colspan="4">PR</td></tr>
</table>

Table J.5-12: VDL Mode 3 RECEIVE NOT READY Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Section J.5.2.1. The packet shall be processed as specified in Section J.6.6.

J.5.3.2.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.3.2.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.3.2.4 Supervisory Packet (SP)

This field shall be set to 2.

J.5.3.2.5 Supervisory Type (ST)

This field shall be set to 1.

J.5.3.2.6 Packet Receive Sequence Number (PR)

This field shall be set as specified in Section J.6.4.4.

J.5.3.3 VDL Mode 3 CLEAR CONFIRMATION

J.5.3.3.1 General

The format of this packet shall be as specified in Table J.5-13.

	MSB				Bit Number			LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	TC		SN					
3	CH		AM					
4	AG							

Table J.5-13: VDL Mode 3 CLEAR CONFIRMATION Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Sections J.5.2.1 and J.5.2.5. The packet shall be processed as specified in Section J.6.3.

J.5.3.3.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.3.3.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.3.3.4 Supervisory Packet (SP)

This field shall be set to 1.

J.5.3.3.5 Supervisory Type (ST)

This field shall be set to 3.

J.5.3.4 VDL Mode 3 RESET CONFIRMATION

J.5.3.4.1 General

The format of this packet shall be as specified in Table J.5-14.

	MSB			**Bit Number**				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	
2	FILL		SN					
3	CH			FILL				

Table J.5-14: VDL Mode 3 RESET CONFIRMATION Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Section J.5.2.1. The packet shall be processed as specified in Section J.6.7.

J.5.3.4.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.3.4.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.3.4.4 Supervisory Packet (SP)

This field shall be set to 2.

J.5.3.4.5 Supervisory Type (ST)

This field shall be set to 3.

J.5.3.5 VDL Mode 3 REJECT PACKET

J.5.3.5.1 General

The format of this packet shall be as specified in Table J.5-15.

	MSB			**Bit Number**				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		SS	
2	FILL		SN					
3	CH				PR			

Table J.5-15: VDL Mode 3 REJECT Packet

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in Section J.5.2.1. The packet shall be processed as specified in Section J.6.8.

J.5.3.5.2 Data Packet Type (DP)

This field shall be set to 0.

J.5.3.5.3 VSP Packet Type (VP)

This field shall be set to 1.

J.5.3.5.4 Supervisory Packet (SP)

This field shall be set to 3.

J.5.3.5.5 Supervisory Type (ST)

This field shall be set to 3.

J.5.3.5.6 Supervisory Subset (SS)

This field shall be set to 1.

J.5.3.5.7 Packet Receive Sequence Number (PR)

This field shall be set as specified in Section J.6.4.4.

J.6 XDCE Operations

The ADCE process within the ANI acts as a peer process to the GDCE process in the GNI.

J.6.1 State Transitions

The XDCE shall operate as a state machine. Upon entering a state, the XDCE shall perform the actions specified in Table J.6-1. If a state transition is specified, the actions taken shall be as specified in Table J.11-11 through Table J.11-18.

> Note 1: *The next state transition (if any) that occurs when the XDCE receives a packet from the peer XDCE is specified by Table J.11-11 through Table J.11-15. The same transitions are defined in Table J.11-16 through Table J.11-18 when the XDCE receives a packet from the DCE (via the Internetworking Process).*

> Note 2: *The XDCE state hierarchy is the same as for the DCE as presented in Table J.4-1, except that states r2, r3 and p5 are omitted.*

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Table J.6-1: DCE Actions at State Transition

DCE STATE	STATE DEFINITION	ACTION THAT SHALL BE TAKEN WHEN ENTERING THE STATE
r1	PACKET LEVEL READY	Return all SVCs to the p1 state (see p1 state explanation).
r2	DTE RESTART REQUEST	Return each SVC to the p1 state (see p1 state explanation). Issue a RESTART CONFIRAMATION to the DTE.
r3	DCE RESTART REQUEST	Issue a RESTART REQUEST to the DTE. Unless entered via the r2 state, send a RESTART REQUEST to the internetworking process.
P1	READY	Release all resources assigned to SVC. Break the correspondence between the DTE/DCE SVC and the ADCE.GDCE SVC (the ADCE/GDCE SVC may not yet be in the p1 state).
P2	DTE CALL REQUEST	Determine if sufficient resources exist to support the request; if so, allocate resources and forward CALL REQUEST packet to the internetworking process; if not, enter DCE CLEAR REQUEST to DTE state (p7). Determination of resources and allocation is as defined in ISO 8208.
P3	DCE CALL REQUEST	Determine if sufficient resources exist to support the request; if so allocate resources and forward CALL REQUEST packet to the DTE; if not, send a CLEAR REQUEST packet to the reformatting process. Determination of resources and allocation is as defined in ISO 8208.
P4	DATA TRANSFER	No action.
P5	CALL COLLISION	Reassign outgoing call to another SVC (the DTE in its call collision state ignores the incoming call) and enters the DCE CALL REQUEST state (p3) for that new SVC.
P6	DTE CLEAR REQUEST	Release all resources assigned to the SVC, send a CLEAR CONFIRMATION packet tot the DTE and enter p1 state.
P7	DCE CLEAR REQUEST to DTE	Forward CLEAR REQUEST packet to DTE
d1	FLOW CONTROL READY	No action.
d2	DTE RESET REQUEST	Remove Data Packets transmitted to the DTE from window; discard any DATA packets that represent partially transmitted M-bit sequences and discard any INTERRUPT packet awaiting transfer to the DTE; reset all window counters to zero; set any timers and retransmission parameters relating to DATA and INTERRUPT transfer to their initial value. Send RESET CONFIRMATION packet to DTE. Return SVC to d1 state.
d3	DCE RESET REQUEST to DTE	Remove Data Packets transmitted to the DTE from window; discard any DATA packets that represent partially transmitted M-bit sequences and discard any INTERRUPT packet awaiting transfer to the DTE; reset all window counters to zero; set any timers and retransmission parameters relating to DATA and INTERRUPT transfer to their initial value. Forward RESET REQUEST packet to DTE.
i1	DTE INTERRUPT READY	No action.
i1	DTE INTERRUPT SEND	Forward INTERRUPT packet received from DTE to internetworking process.
j1	DCE INTERRUPT READY	No action.
j2	DCE INTERRUPT SENT	Forward INTERRUPT packet received from internetworking process to DTE
f1	DCE RECEIVE READY	No action.
f2	DCE RECEIVE NOT READY	No action.
g1	DTE RECEIVE READY	No action.
g2	DTE RECEIVE NOT READY	No action.

J.6.2 Disposition of Packets

J.6.2.1 Receipt of Peer XDCE

Upon receipt of a packet from the peer XDCE, the packet shall be forwarded or not forwarded to the DCE (via the internetworking Process) according to the parenthetical instructions contained in Tables J.11-11 to J.11-15. If no parenthetical instruction is listed or if the parenthetical instruction indicates "do not forward", the packet shall be discarded.

J.6.3 SVC Call Setup and Clear Procedure

J.6.3.1 Setup Procedures

Upon receipt of a CALL REQUEST from the DCE or peer XDCE, the XDCE shall determine if sufficient resources exist to operate the SVC. This shall include: sufficient buffer space and an available p1 state SVC. Upon acceptance of the CALL REQUEST from the DCE, the VDL Mode 3 CALL REQUEST Packet shall be forwarded to the Link Level. Upon acceptance of a CALL REQUEST from the peer XDCE, the VDL Mode 3 CALL REQUEST shall be sent to the internetworking process.

J.6.3.2 Aborting a Call Request

If the DTE and the peer XDCE abort a call before they have received a CALL ACCEPT Packet, they shall indicate this condition by issuing a CLEAR REQUEST Packet. Procedures for handling these cases shall be as specified in Table J.11-12.

J.6.3.3 Virtual Call Clearing

J.6.3.3.1 Unsupported Call Request (XDCE)

If the XDCE receives a CALL REQUEST from the Internetworking Process that it cannot support, it shall initiate a CLEAR REQUEST Packet that is sent to the DCE for transfer to the DTE (the DCE thus enters the DCE Clear Request to DTE State p7). The diagnostic and cause codes shall be set as follows:

a) No Channel Number Available, DC=71, CC=133
b) Buffer Space Not Available, DC=71, CC=133
c) Facility Not Available, DC=65, CC=131
d) Illegal Called Address, DC=67, CC=141
e) Illegal Calling Address, DC=68, CC=141
f) DTE Not Operational, DC=162, CC=141

In all cases, bit 8 of the Cause Field shall be set to ONE to indicate that the problem originated in the VDL Mode 3 Subnetwork and not the DTE.

J.6.3.3.2 Unsupported Peer Call Request

If the XDCE receives a CALL REQUEST Packet from the peer XDCE (via the Internetworking Process) which it cannot support, it shall enter the state p7. The Cause Field shall be as specified above.

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J.6.3.4 Clear Confirmation

When the XDCE receives a CLEAR CONFIRMATION Packet, the remaining resources allocated to manage the SVC shall be released and the SVC shall be returned to the p1 State. CLEAR CONFIRMATION Packets shall not be transferred to the DCE.

J.6.3.5 Clear Collision

A clear collision occurs at the XDCE when it receives a CLEAR REQUEST Packet from the DCE and then receives a CLEAR REQUEST Packet from the peer XDCE (or vice versa). In this event the XDCE does not expect to receive a CLEAR CONFIRMATION Packet for this SVC and shall consider the clearing complete.

J.6.4 Data Transfer and Interrupt Procedures

J.6.4.1 General

J.6.4.1.1 Independent SVC

Data transfer and interrupt procedures shall apply independently to each SVC. The contents of the User Data Field shall be passed transparently to the DCE or the peer XDCE. Data shall be transferred in the order dictated by the sequence numbers assigned to the data packets.

J.6.4.1.2 Flow Control Ready State

To transfer packets, the SVC shall be in a Flow Control Ready State (d1).

J.6.4.2 VDL Mode 3 Packet Size

J.6.4.2.1 Maximum Size

The maximum size of a VDL Mode 3 data packet shall be 923 octets in length. The 923 octet maximum data packet size coupled with the 6 octet overhead of the Single Information frame and one octet payload identification creates the 930 octet maximum imposed by the TDMA MAC layer and its ability to send up to 15 slots, each RS (72,62) encoded for a single data access.

J.6.4.2.2 Less Than Maximum Size

The VDL Mode 3 subnetwork shall allow packets of less than the maximum size to be transferred.

J.6.4.3 Flow Control Window Size

The flow control window size of the VDL Mode 3 subnetwork shall be independent of that used on the DTE/DCE interface. The VDL Mode 3 subnetwork window size shall be 15 packets in the uplink and downlink directions.

J.6.4.4 SVC Flow Control

J.6.4.4.1 Sequence Number

Flow control shall be managed by means of a sequence number for received packets (PR) and one for packets that have been sent (PS). A sequence number (PS) shall be assigned for each VDL Mode 3 DATA Packet generated by the XNI for each SVC. The first VDL Mode 3 DATA Packet transferred by the XDCE to the Link level when the SVC has just entered the Flow Control Ready State shall be numbered zero. The first VDL Mode 3 packet received from the peer XDCE after an SVC has just entered the Flow Control Ready State shall be numbered zero. Subsequent packets shall be numbered consecutively.

J.6.4.4.2 VDL Mode 3 Data Packets

A source of VDL Mode 3 DATA Packets (the ADCE or GDCE) shall not send (without permission from the receiver) more VDL Mode 3 DATA Packets than would fill the flow control window. The receiver shall give explicit permission to send more packets.

J.6.4.4.3 Permission Information

The permission information shall be in the form of the next expected packet sequence number, and shall be denoted PR. If a receiver wishes to update the window and it has data to transmit to the sender, a VDL Mode 3 Packet shall be used for Information transfer. If the window must be updated and no data is to be sent, a VDL Mode 3 RECEIVE READY (RR) or VDL Mode 3 RECEIVE NOT READY (RNR) Packet shall be sent. At this point the 'sliding window' shall be moved to begin at the new PR value. The XDCE shall not be authorized to transfer 15 more packets without acknowledgment.

J.6.4.4.4 Next VDL Mode 3 Data Packets

When the sequence number (PS) of the next VDL Mode 3 DATA Packet to be sent is in the range PR#PS#PR+14 (modulo 16), the sequence number shall be defined to be "in the window" and the XDCE shall be authorized to transmit the packet. Otherwise the sequence number (PS) of the packet shall be defined to be "outside the window" and the XDCE shall not transmit the packet to the peer XDCE.

J.6.4.4.5 Next in Sequence, Within Window

When the sequence number (PS) of the packet received is next in sequence and within the window, the XDCE shall accept this packet. Receipt of a packet shall be considered an error if it contains a sequence number (PS)

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a. outside the window, or
b. out of sequence, or
c. not equal to zero for the first data packet after entering Flow control Ready state.

J.6.4.4.6 Valid PS Number of VDL Mode 3 Data Packet

The receipt of a VDL Mode 3 DATA Packet with a valid PS number (i.e. the next PS in sequence) shall cause the lower window PR to be changed to that PS value plus 1. The packet receive sequence number (PR), shall be conveyed to the originating XNI by a VDL Mode 3 DATA, RECEIVE READY, RECEIVE NOT READY, or REJECT Packet. A valid PR value shall be transmitted by the XDCE to the peer XDCE after the receipt of 8 packets provided that sufficient buffer space exists to store 15 packets. Incrementing the PR and PS Fields shall be performed using modulo 16 arithmetic.

J.6.4.4.7 Transfer of Packet

A copy of a packet shall be retained until the user data has been successfully transferred. Following successful transfer, the PS value shall be updated.

J.6.4.4.8 Update of PR Value

The PR value for user data shall be updated as soon as the required buffer space for the window (as determined by flow control management) is available within the DCE.

J.6.4.4.9 Flow Control

Flow control management shall be provided between the DCE and XDCE.

J.6.4.5 Interrupt Procedures for Switched Virtual Circuits

J.6.4.5.1 Non-Use of Flow Control

If user data is to be sent via the Mode 3 subnetwork without following the flow control procedures, the interrupt procedures shall be used. The interrupt procedure shall have no effect on the normal data packet and flow control procedures. The processing of the VDL Mode 3 INTERRUPT Packet shall occur as soon as it is received by the XDCE.

> Note: *The use of clear, reset, and restart procedures can cause interrupt data to be lost.*

J.6.4.5.2 Interrupt Processing

Interrupt processing shall have precedence over any other processing from the SVC occurring at the time of the interrupt.

J.6.4.5.3 Unconfirmed Interrupt

The reception of a VDL Mode 3 INTERRUPT Packet before the previous interrupt of the SVC has been confirmed (by the receipt of a VDL Mode 3 INTERRUPT CONFIRMATION Packet) shall be defined as an error.

J.6.5 Receive Ready Procedure

J.6.5.1 Transfer of PR Value, Without VDL Mode 3 Packet

A VDL Mode 3 RR packet shall be sent if no VDL Mode 3 DATA Packets (that normally contain the updated PR value) are available for transmittal and it is necessary to transfer the latest PR value. It also shall be sent to terminate a receive not ready condition.

J.6.5.2 Update of PR

Receipt of the VDL Mode 3 RECEIVE READY Packet by the XDCE shall cause the XDCE to update its value of PR for outgoing SVC. It shall not be taken as a demand for retransmission of packets that have already been transmitted and are still in the window.

J.6.5.3 Receive Ready State

Upon receipt of the VDL Mode 3 RECEIVE READY Packet the XDCE shall go into the ANI(GNI) Receive Ready State, g1.

J.6.6 Receive Not Ready Procedure

J.6.6.1 Clearing of RNR

The VDL Mode 3 RECEIVE NOT READY (RNR) Packet shall be used to indicate a temporary inability to accept additional DATA Packets for the given SVC. The VDL Mode 3 RNR condition shall be cleared by the receipt of a VDL Mode 3 RR Packet or a VDL Mode 3 REJECT Packet.

J.6.6.2 Update of PR Value

When the XDCE receives a VDL Mode 3 RNR Packet from the peer XDCE it shall update its value of PR for the SVC and stop transmitting DATA Packets on the SVC to the XNI. The XDCE shall go into the ANI/(GNI) Receive Not Ready State, g2.

J.6.6.3 ADCE Receive Not Ready State

The XDCE shall transmit a VDL Mode 3 RNR Packet to the peer XDCE if it is unable to receive from the peer XDCE any more VDL Mode 3 DATA Packets on the indicated SVC. Under these conditions the XDCE shall go into the ADCE(GDCE) Receive Not Ready State, f2.

J.6.7 Reset Procedures

J.6.7.1 Reception of Reset Request

When the XDCE receives a VDL Mode 3 RESET REQUEST Packet from either the peer XDCE or the DCE or due to an error condition performs its own reset, the following actions shall be taken.

a. Those VDL Mode 3 DATA Packets that have been transmitted to the peer XDCE shall be removed from the window.
b. Those VDL Mode 3 DATA Packets that are not transmitted to the peer XDCE but are contained in an M-bit sequence for which some packets have been transmitted shall be deleted from the queue of DATA packets awaiting transmission.
c. Those VDL Mode 3 DATA Packets received from the peer XDCE that are part of an incomplete M-bit sequence shall be discarded.
d. The lower window edge shall be set to zero and the next packet sent shall have a sequence number (PS) of zero.
e. Any outstanding VDL Mode 3 INTERRUPT Packets to or from the peer XDCE shall be left unconfirmed.
f. Any Mode 3 INTERRUPT Packet awaiting transfer shall be discarded.

J.6.7.2 Data Transfer State

The reset procedure shall apply to the Data Transfer State. In any other state the reset procedure shall be abandoned.

J.6.8 Reject Procedures

J.6.8.1 Incorrect Format

When the XDCE receives from the peer XDCE a VDL Mode 3 DATA Packet with incorrect format or whose packet sequence number (PS) is not within the defined window, it shall discard the received packet and send a VDL Mode 3 REJECT Packet to the peer XDCE via the Internetworking Process. Otherwise, the 8208 subnetwork interface will never be capable of resequencing out of order packets. The VDL Mode 3 Packet shall indicate a value of PR for which retransmission of the VDL Mode 3 DATA Packets is to begin. The XDCE shall discard subsequent out-of-sequence VDL Mode 3 DATA Packets whose receipt occurs while the VDL Mode 3 REJECT Packet response is still outstanding.

~~J.6.8.1 Incorrect Format~~

~~When the XDCE receives from the peer XDCE a VDL Mode 3 DATA Packet with incorrect format or whose packet sequence number (PS) is not within the defined window or is out of sequence, it shall discard the received packet and send a VDL Mode 3 REJECT Packet to the peer XDCE via the Internetworking Process. The VDL Mode 3 Packet shall indicate a value of PR for which~~

~~retransmission of the VDL Mode 3 DATA Packets is to begin. The XDCE shall discard subsequent out-of-sequence VDL Mode 3 DATA Packets whose receipt occurs while the VDL Mode 3 REJECT Packet response is still outstanding.~~

J.6.8.2 Update of Lower Window Value

When the XDCE receives a VDL Mode 3 REJECT Packet from the peer XDCE, it shall update its lower window value with the new value of PR and begin to (re)transmit packets with a sequence number of PR.

J.6.8.3 Reject Indications

Reject indications shall not be transferred to the DCE. If the ISO 8208 interface supports the reject procedures, the reject indications occurring on the ISO 8208 interface shall not be transferred between the DCE and the XDCE.

J.6.9 Packet Resequencing and Duplicate Suppression

J.6.9.1 General

Resequencing shall be performed independently for the uplink and downlink transfers of each SVC. The following variables and parameters shall be used:

SNR	A 6-bit variable indicating the sequence number of a received packet on a specific SVC. It is contained in the SN field of the packet.
NESN	The next expected sequence number following a series of consecutive sequence numbers.
HSNR	The highest value of SNR in the resequencing window.
Tq	Resequencing timers associated with a specific SVC.

All operations involving the sequence number (SN) shall be performed modulo 64.

J.6.9.2 Duplication Window

The range of SNR values between NESN - 32 and NESN - 1 inclusive shall be denoted the duplication window.

J.6.9.3 Resequencing Window

The range of SNR values between NESN + 1 and NESN + 31 inclusive shall be denoted the resequencing window. Received packets with a sequence number value in this range shall be stored in the resequencing window in sequence number order.

J.6.9.4 Transmission Functions

J.6.9.4.1 SN Field Initialization

For each SVC, the first packet sent to establish a connection (the first VDL Mode 3 CALL REQUEST or first VDL Mode 3 CALL ACCEPT packet) shall cause the value of the SN Field to be initialized to 0. The value of the SN field shall be incremented after transmission (or retransmission) of each packet.

J.6.9.4.2 Maximum Number of Unacknowledged SN

The maximum number of unacknowledged sequence numbers shall be 32 consecutive SN numbers. When this condition is reached, all further SVC packets for that channel shall be held by the XNI until acknowledgment of successful delivery is received from the connected radio for the oldest packet in transit.

> *Note: A limit on the number of unacknowledged packets is required since the SN field is six bits long and therefore has a maximum of 64 different values before the values repeat.*

J.6.9.5 Receive Functions

J.6.9.5.1 General

The resequencing algorithm shall maintain the variables HSNR and NESN for each SVC. NESN shall be initialized to 0 for all SVCs and shall be reset to 0 when the SVC reenters the channel number pool.

J.6.9.5.2 Processing of Packets within the Duplication Window

If a packet is received with a sequence number value within the duplication window, the packet shall be discarded.

J.6.9.5.3 Processing of Packets within the Resequencing Window

If a packet is received with a sequence number within the resequencing window, it shall be discarded as a duplicate if a packet with the same sequence number has already been received and stored in the resequencing window. Otherwise, the packet shall be stored in the resequencing window. Then, if no Tq timers are running, HSNR shall be set to the value of SNR for this packet and a Tq timer shall be started with its initial value. If at least one Tq timer is running, and SNR for the packet is greater than or equal to HSNR + 2, a new Tq timer shall be started and the value of HSNR shall be updated. If at least one Tq timer is running, and SNR for this packet is equal to HSNR + 1, the value of HSNR shall be updated.

J.6.9.5.4 Release of Packets to the XDCE

If a packet is received with a sequence number equal to NESN, the following procedure shall be followed:

a. This packet and any packets already stored in the resequencing window up to the next missing sequence number, shall be passed to the XDCE and
b. NESN shall be set to 1 + the value of the sequence number of the last packet passed to the XDCE.
c. The Tq timer associated with any of the released packets shall be stopped.

J.6.9.6 Tq Timer Expiration

If a Tq timer expires, the following procedures shall be followed:

a. NESN shall be incremented until the next missing sequence number in the resequencing window is detected.
b. Any stored packets with sequence numbers that are no longer in the resequencing window shall be forwarded to the XDCE.
c. The Tq timer associated with any released packets shall be stopped.

J.7 Multiplexing

When multiplexing multiple VDL Mode 3 packets into a single VDL Mode 3 Data link frame. The following procedures shall be used.

J.7.1 Multiplexing Optimization, Recommendation

When multiple packets are awaiting transfer to the same XNI, they should be multiplexed into a single frame in order to optimize throughput, provided that packets associated with SVCs of different priorities are not multiplexed together.

J.7.2 Structure

The structure of the multiplexed packets shall be as follows:

HEADER: 8	LENGTH: 16	1^{ST} PACKET: v	LENGTH: 16	2^{ND} PACKET: v

Packet structure

J.7.2.1 Multiplexing Header

The header for the multiplexed packets shall be as specified in Table J.7-1.

Table J.7-1: Multiplexing Header Packet Structure

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	MSB			**Bit Number**				LSB
Octet	8	7	6	5	4	3	2	1
1	DP	VP	SP		ST		FILL	

Where:

Data packet type (DP) = 0
VSP Packet type (VP) = 1
Supervisory packet (SP) = 3
Supervisory type (ST) = 2

J.7.2.2 Length Field

This field shall contain the length of the following packet in octets. The length field shall be defined as follows:

Length $n_{16}\ n_{15}\ n_{14}\ n_{13}\ n_{12}\ n_{11}\ n_{10}\ n_{09}\ n_{08}\ n_{07}\ n_{06}\ n_{05}\ n_{04}\ n_{03}\ n_{02}\ n_{01}$

J.8 VDL Mode 3 Subnetwork Management

J.8.1 Ground Subnetwork Address - DTE address Correlation

The ANI shall construct and manage a VDL Mode 3 Ground Subnetwork Address - DTE cross reference table whose entries are the VDL Mode 3 data link Ground Subnetwork Address and the ground DTE address associated with the ground ATN router. This table is used to maintain the connection context to associate link layer PDUs with the appropriate SVC, as well as providing a means to maintain a connection through an old SVC while establishing a new SVC during handoff. Each entry of the cross reference table shall consist of the 6 bit Ground Subnetwork Address and the 8 bit binary representation of the Ground DTE.

J.8.2 Support for the DTE

J.8.2.1 GNI Connectivity Reporting

The GNI shall notify the ground DTE of the availability of a VDL Mode 3 data link equipped aircraft ("join event"). The GNI shall also inform the ground DTE when such an aircraft is no longer in contact via that GNI ("leave event").

J.8.2.2 ANI Connectivity Reporting

The ANI shall notify the aircraft DTE whenever the last remaining entry for a ground DTE is deleted from the Ground Subnetwork Address - DTE cross reference table.

J.8.3 Error Procedures

J.8.3.1 Active Channel Determination

J.8.3.1.1 Procedure for d1 State

The XNI shall monitor the activity of all SVCs not in a READY state (p1). If an SVC is in the (XDCE) FLOW CONTROL READY state (d1) for more than Tx seconds (the active channel timer) without sending a VDL Mode 3 RR, RNR, DATA, or REJECT packet, then:

a) If the last packet sent was a VDL Mode 3 REJECT packet, the XNI shall resend the VDL Mode 3 REJECT packet.
b) Otherwise, the XNI shall send a VDL Mode 3 RR or RNR packet as appropriate, to its peer.

J.8.3.1.2 Procedure for Other States

If an XDCE SVC is in the p2, p3, p6, p7, d2 or d3 state for more than Tx seconds, a VDL Mode 3 CLEAR REQUEST packet shall be sent to the local DTE with CC = 137 and DC = 255. Bit 8 of the cause field shall be set to ONE.

J.9 System Timers

The values for Tx and Tq timers shall conform to the values given in Table J.9-1.

Table J.9-1: VDL Mode 3 Subnetwork Timers

TIMER NAME	TIMER LABEL	NOMINAL VALUE
Active channel timer	Tx	
ANI		120 sec
GNI		60 sec
Packet resequencing	Tq	20 sec

J.10 Compression System Parameters

The parameters used by the 8208 compression shall be as listed in Table J.10-1a. The 8208 compression parameters shall be determined by the XNI by exchange of the CTRL frame, if the default values are not used. Table J.10-1a identifies which parameters are mandatory and those that are optional. These parameters shall take the place of the subparameter ID, length, and value fields in Table 3-72a, with the Network Type field indicating hexadecimal 00.

Table J.10-1a: 8208 Compression System Parameters

Symbol	Parameter Name	Minimum	Maximum	Mode 3 Default	Increment	Modification
VER	Compression Version Number	0	255	1 *	1	M

GDTE	Ground DTE Address	0	255	**	1	M
ADSA	Aircraft DTE Sub-address	0	15	0	1	M
MBIT	VDL Mode 3 M-bit segmentation size	52	920	610	1	O

* Version 1 is the current version of this document.
** Local Ground Issue

J.10.1 ADSA (Aircraft DTE Sub-Address Field)

The aircraft Sub-Address field represents the sub-address for specific DTEs onboard an aircraft. The XID format for the ADSA parameter shall be defined in Table J.10-1b.

Table J.10-1b: ADSA Parameter

Parameter ID	1 0 0 0	0 1 0 0	ADSA parameter
Parameter Length	0 0 0 0	0 0 0 1	
Parameter Value	$v_8v_7v_6v_5$	$v_4v_3v_2v_1$	

J.10.2 GDTE (Ground DTE Field)

The ground DTE address field represents the ground DTE address converted to BCD as defined in Section J.2.2.1. The XID format for the GDTE parameter shall be defined in Table J.10-2.

Table J.10-2: GDTE Parameter

Parameter ID	0 1 0 1	0 1 0 1	GDTE parameter
Parameter Length	0 0 0 0	0 0 0 1	
Parameter Value	$v_8v_7v_6v_5$	$v_4v_3v_2v_1$	

J.10.3 VER (8208 Compression Version Number)

The 8208 Compression Version Number identifies the version of the subnetwork compression. This appendix identifies version 1 of 8208 compression. The XID format for the VER parameter shall be defined in Table J.10.3.

Table J.10-3: VER Parameter

Parameter ID	0 1 0 1	0 1 1 0	VER parameter
Parameter Length	0 0 0 0	0 0 0 1	
Parameter Value	$v_8v_7v_6v_5$	$v_4v_3v_2v_1$	

J.10.4 M-BIT

The M-BIT parameter shall represent the user data segmentation size used by the XNI. The M-BIT parameter is an optional parameter with a default size specified as 176 octets. The XID format for the M-BIT shall be as defined in Table J.10.4.

> Note: *The 176 octet default M-bit segmentation plus 3 octet VDL Mode 3 data packet header, one octet payload field, and six octet DLS header form a full 3 slot TDMA segment size of 186 octets*

Table J.10-4: M-BIT Parameter

Parameter ID	0 1 0 1	0 1 1 1	M-BIT parameter
Parameter Length	0 0 0 0	0 0 1 0	
Parameter Value	$v_{16}v_{15}v_{14}v_{13}$	$v_{12}v_{11}v_{10}v_{09}$	
	$v_{08}v_{07}v_{06}v_{05}$	$v_{04}v_{03}v_{02}v_{01}$	

J.11 DCE and XDCE State Tables

J.11.1 State Table Requirements

The DCE and XDCE shall function as specified in state Tables J.11-1 to J.11-18. State Tables J.11-11 through J.11-18 shall be applied to:

a) ANI state transitions when the XDCE of XNI terms in parenthesis are omitted; and

b) GNI state transitions when the terms in parenthesis are used and the XDCE or XNI preceding them are omitted.

J.11.2 Diagnostic and Cause Codes

The table entries for certain conditions indicate a diagnostic code that shall be included in the packet generated when entering the state indicated. The term "D =" shall define the diagnostic code. When "A = DIAG," the action taken shall be to generate an ISO 8208 DIAGNOSTIC packet and transfer it to the DTE; the diagnostic code indicated shall define the entry in the diagnostic field of the packet. In the cause field of any packet type, bit 8 of the cause field shall always be set to zero, indicating that the condition was detected by the DTE/DCE interface. Unless otherwise specified, the clearing cause code and the reset cause code shall be set as specified in ISO 8208.

Note 1: *The tables provided below specify state requirements in the following order:*

J.11-1	DCE Special Cases
J.11-2	DTE Effect on DCE Restart States
J.11-3	DTE Effect on DCE Call Setup and Clearing States
J.11-4	DTE Effect on DCE Reset States
J.11-5	DTE Effect on DCE Interrupt Transfer States
J.11-6	DTE Effect on DCE Flow Control Transfer States
J.11-7	XDCE Effect on DCE Restart States
J.11-8	XDCE Effect on DCE Call Setup and Clearing States
J.11-9	XDCE Effect on DCE Reset States
J.11-10	XDCE Effect on DCE Interrupt Transfer States
J.11-11	GNI(ANI) Effect on ADCE (GDCE) Packet Layer Ready States
J.11-12	GNI(ANI) Effect on ADCE (GDCE) Call Setup and Clearing States
J.11-13	GNI(ANI) Effect on ADCE (GDCE) Reset States
J.11-14	GNI(ANI) Effect on ADCE (GDCE) Interrupt Transfer States
J.11-15	GNI(ANI) Effect on ADCE (GDCE) Flow Control Transfer States
J.11-16	DCE Effect on ADCE (GDCE) Call Setup and Clearing States
J.11-17	DCE Effect of ADCE (GDCE) Reset States
J.11-18	DCE Effect on ADCE (GDCE) Interrupt Transfer States

Notes:

1. *All tables specify both ANI and GNI actions*

2. *Within the VDL Mode 3 subnetwork, states p6 and d2 are transient states.*

3. *References to "notes" in the state tables refer to table-specific notes that follow each state table.*

4. *All diagnostic and cause codes are interrupted as decimal numbers.*

5. *An SVC between an ADCE and a GDCE may be identified by a temporary and/or permanent channel number, as defined in Section J.5.1.1.*

Table J.11-1: DCE Special Cases

Received from DTE	**DCE special cases Any state**
Any packet less than 2 bytes in length (including a valid data link level frame containing no packet)	A= DIAG D =38
Any packet with an invalid general format identifier	A = DIAG D = 40
Any packet with a valid general format identifier and an assigned logical channel identifier (includes a logical channel identifier of 0)	See Table J.11-2

Table J.11-2: DTE Effect on DCE Restart States

	DCE Restart States (see Note 5)		
Packet Received from DTE	**PACKET LEVEL READY (see Note 1) r1**	**DTE RESTART REQUEST r2**	**DCE RESTART REQUEST r3**
Packets having a packet type identifier shorter than 1 byte and logical channel identifier not equal to 0	See Table J.11-3	A = ERROR S = r3 D = 38 (see Note 4)	A = DISCARD
Any packet, except RESTART, REGISTRATION (if supported) with a logical channel identifier of 0	A = DIAG D = 36	A = DIAG D = 36	A = DIAG D = 36
Packet with a packet type identifier that is undefined or not supported by DCE	See Table J.11-3	A = ERROR S = r3 D = 33 (see Note 4)	A = DISCARD
RESTART REQUEST, RESTART CONFIRMATION, of REGISTRATION (if supported) packet with a logical channel identifier unequal to 0	See Table J.11-3	A = ERROR S = r3 D = 41 (see Note 4)	A = DISCARD
RESTART REQUEST	A = NORMAL (forward) S = r2	A = DISCARD	A = NORMAL S = p1 or d1 (see Note 2)
RESTART CONFIRMATION	A = ERROR S = r2 D = 17 (see Note 6)	A = ERROR S = r3 D = 18 (see Note 4)	A = NORMAL S = p1 or D1 (see Note 2)
RESTART REQUEST OR RESTART CONFIRMATION packet with a format error	A = DIAG D = 38, 39, 81, or 82	A = DISCARD	A = ERROR D = 38, 39, 81, or 82
REGISTRATION REQUEST of REGISTRATION CONFIRMATION packets (see Note 3)	A = NORMAL	A = NORMAL	A = NORMAL
REGISTRATION REQUEST of REGISTRATION CONFIRMATION packet with format error (see Note 3)	A = DIAG D = 38, 39, 81 or 82	A = ERROR S = r3 D = 38, 39, 81, or 82 (see Note 4)	A = ERROR D = 38, 39, 81 or 82
Call setup, call clearing, DATA, interrupt, flow control, or reset packet	See Table J.11-3	A = ERROR S = r3 D = 18	A = DISCARD

Note 1: *The VDL Mode 3 subnetwork has no restart states. Receipt of a RESTART REQUEST causes the DCE to respond with a RESTART CONFIRMATION. The RESTART REQUEST packet is forwarded to the internetworking process, which issues clear requests for all SVCs associated with the DTE. The DCE enters the r3 state only as a result of an error detected on the DTE/DCE interface.*

Note 2: The SVC channels are returned to state p1, the PVC channels are returned to state d1.

Note 3: The use of the registration facility is optional on the DTE/DCE interface.

Note 4: No action is taken within the VDL Mode 3 subnetwork.

Note 5: Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates the received packet is to be cleared for the XNI buffers; and INVALID indicates that packet/state combination cannot occur.

Note 6: The error procedure consists of entering the r3 state, and sending a RESTART REQUEST to the internetworking process.

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Table J.11-3: DTE Effect on DCE Call Setup and Clearing States

	DCE Call Setup and Clearing States (see Note 5)						
Packet Received from DTE	**READY** **p1**	**DTE CALL REQUEST** **p2**	**DCE CALL REQUEST** **p3**	**DATA TRANSFER** **p4**	**CALL COLLISION** **p5**	**DTE CLEAR REQUEST** **p6**	**DCE CLEAR REQUEST to DTE** **p7**
Packets having a packet type identifier shorter than 1 byte	A = ERROR S = p7 D = 38	A = ERROR S = p7 D = 38 (see Note 2)	A = ERROR S = p7 D = 38 (see Note 2)	See Table J.11-4	A = ERROR S = p7 D = 38 (see Note 2)	A = ERROR S = p7 D = 38 (see Note 2)	A = DISCARD
Packets having a packet type identifier which is undefined or not supported by DCE	A = ERROR S = p7 D = 33	A = ERROR S = p7 D = 33 (see Note 2)	A = ERROR S = p7 D = 33 (see Note 2)	See Table J.11-4	A = ERROR S = p7 D = 33 (see Note 2)	A = ERROR S = p7 D = 33 (see Note 2)	A = DISCARD
RESTART REQUEST, RESTART CONFIRMATION or REGISTRATION packet with logical channel identifier unequal to 0	A = ERROR S = p7 D = 41	A = ERROR S = p7 D = 41 (see Note 2)	A = ERROR S = p7 D = 41 (see Note 2)	See Table J.11-4	A = ERROR S = p7 D = 41 (see Note 2)	A = ERROR S = p7 D = 41 (see Note 2)	A = DISCARD
CALL REQUEST	A = NORMAL S = p2 (forward)	A = ERROR S = p7 D = 21 (see Note 2)	A = NORMAL S = p5	A = ERROR S = p7 D = 23 (see Note 2)	A = ERROR S = p7 D = 24 (see Note 2)	A = ERROR S = p7 D = 25 (see Note 2)	A = DISCARD
CALL ACCEPT	A = ERROR S = p7 D = 41	A = ERROR S = p7 D = 21 (see Note 2)	A= NORMAL S = p4 or A = ERROR S = p7 D = 42 (see Notes 2 and 3)	A = ERROR S = p7 D = 23 (see Note 2)	A = ERROR S = p7 D = 24 (see Note 2 and 4)	A = ERROR S = p7 D = 25 (see Note 2)	A = DISCARD
CLEAR REQUEST	A = NORMAL S = p6	A = NORMAL s = p6 (forward)	A = NORMAL s = p6 (forward)	A = NORMAL s = p6 (forward)	A = NORMAL s = p6 (forward)	A = DISCARD	A = NORMAL S= p1 (do not forward)
CLEAR CONFIRMATION	A = ERROR S = p7 D = 20	A = ERROR S = p7 D = 21 (see Note 2)	A = ERROR S = p7 D = 22 (see Note 2)	A = ERROR S = p7 D = 23 (see Note 2)	A = ERROR S = p7 D = 24 (see Note 2)	A = ERROR S = p7 D = 25 (see Note 2)	A = NORMAL S = p1 (do not forward)
DATA, interrupt, flow control or reset packet	A = ERROR S = p7 D = 20	A = ERROR S = p7 D = 21 (see Note 2)	A = ERROR S = p7 D = 22 (see Note 2)	See Table J.11-4	A = ERROR S = p7 D = 24 (see Note 2)	A = ERROR S = p7 D = 25 (see Note 2)	A = DISCARD

Note 1: On entering the p5 state, the DCE reassigns the outgoing call to the DTE to another channel (no CLEAR REQUEST is issued) and responds to incoming DTE call as appropriate with a CLEAR REQUEST or CALL ACCEPT packet.

Note 2: The error procedure consists of performing the actions specified when entering the p7 state (including sending a CLEAR REQUEST packet to the DTE) and additionally sending a

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CLEAR REQUEST packet to the XDCE (via the internetworking process).

Note 3: *The use of the fast select facility with a restriction on the response prohibits the DTE from sending a CALL ACCEPT packet.*

Note 4: *The DTE in the event of a call collision must discard the CALL REQUEST packet received from the DCE.*

Note 5: *Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.*

Table J.11-4: DTE Effect on DCE Reset States

	DCE Reset States (see Note 2)		
Packet Received from DTE	**FLOW CONTROL READY d1**	**RESET REQUEST by DTE d2**	**DCE RESET REQUEST to DTE d3**
Packet with a packet type identifier shorter than 1 byte	A = ERROR S = d3 D = 38 (see Note 1)	A = ERROR S = d3 D = 38 (see Note 1)	A = DISCARD
Packet with a packet type identifier that is undefined or not supported by DCE	A = ERROR S = d3 D = 33 (see Note 1)	A = ERROR S = d3 D = 33 (see Note 1)	A = DISCARD
RESTART REQUEST, RESTART CONFIRMATION, or REGISTRATION (if supported) packet with logical channel identifier unequal to 0	A = ERROR S = d3 D = 41 (see Note 1)	A = ERROR S = d3 D = 41 (see Note 1)	A = DISCARD
RESET REQUEST	A = NORMAL S = d2 (forward)	A = DISCARD	A = NORMAL S = d1 (do not forward)
RESET CONFIRMATION	A = ERROR S = d3 D = 27 (see Note 1)	A = ERROR S = d3 D = 28 (see Note 1)	A = NORMAL S = d1 (do not forward)
INTERRUPT packet	See Table J.11-5	A = ERROR S = d3 D = 28 (see Note 1)	A = DISCARD
INTERRUPT CONFIRMATION packet	See Table J.11-5	A = ERROR S = d3 D = 28 (see Note 1)	A = DISCARD
DATA or flow control packet	See Table J.11-6	A = ERROR S = d3 D = 28 (see Note 1)	A = DISCARD
REJECT supported but not subscribed to	A = ERROR S = d3 D = 37 (see Note 1)	A = ERROR S = d3 D = 37 (see Note 1)	A = DISCARD

Note 1: The error procedure consists of performing the specified actions when entering the d3 state (which includes forwarding a RESET REQUEST packet to the DTE) and sending a RESET REQUEST packet to the XDCE (via the internetworking function).

Note 2: Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.

Table J.11-5: DTE Effect on DCE Interrupt Transfer States

	DTE/DCE Interrupt Transfer States (see Note 2)	
Packet Received from DTE	**DTE INTERRUPT READY i1**	**DTE INTERRUPT SENT i2**
INTERRUPT (see Note 1)	A = NORMAL S = I2 (forward)	A = ERROR S = d3 D = 44 (see Note 3)

	DTE/DCE Interrupt Transfer States (see Note 2)	
Packet Received from DTE	**DTE INTERRUPT READY j1**	**DTE INTERRUPT SENT j2**
INTERRUPT CONFIRMATION (see Note 1)	A = ERROR S = d3 D = 43 (see Note 3)	A = NORMAL S = j1 (forward)

Note 1: *If the packet has a format error then the error procedure applies (see Note 3).*

Note 2: *Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.*

Note 3: *The error procedure consists of performing the specified actions when entering the d3 state (which includes forwarding a RESET REQUEST packet to the DTE) and sending a RESET REQUEST packet to the XDCE (via the internetworking process).*

Table J.11-6: DTE Effect on DCE Flow Control Transfer States

Packet Received from DTE	**DCE Flow Control Transfer States (see Notes 2 and 3)**	
	DCE RECEIVE READY f1	**DCE RECEIVE NOT READY f2**
DATA packet with less than 4 bytes	A = ERROR S = d3 D = 38 (see Note 4)	A = DISCARD
DATA packet with invalid PR	A = ERROR S = d3 D =2 (see Note 4)	A = ERROR S = d3 D = 2 (See Note 4)
DATA packet with valid PR but invalid PS or user data field with improper format	A = ERROR S = d3 D = 1 (invalid PS) D = 39 (UD > defined length) D = 82 (UD unaligned) (see Note 4)	A = DISCARD (process PR data)
DATA packet with valid PR, PS and user data field format	A = NORMAL (forward)	A = DISCARD (process PR data)

Packet Received from DTE	**DCE Flow Control Transfer States (see Notes 2 and 3)**	
	DCE RECEIVE READY g1	**DCE RECEIVE NOT READY g2**
RR, RNR, or REJECT packet with less than 4 bytes (see Note 1)	A = DISCARD	A = DISCARD
RR, RNR, or REJECT packet with an invalid PR	A = ERROR S = d3 D =2 (see Note 4)	A = ERROR S = d3 D = 2 (see Note 4)
RR packet with a valid PR	A = NORMAL	A = NORMAL S = g1
RNR packet with a valid PR	A = NORMAL S = g2	A = NORMAL
REJECT packet with a valid PR	A = NORMAL	A = NORMAL S = g1

Note 1: *The reject procedures are not required.*

Note 2: *The RR, RNR and REJECT procedures are a local DTE/DCE matter and the corresponding packets are not forwarded to the XDCE.*

Note 3: *Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.*

Note 4: The error procedure consists of performing the specified actions when entering the d3 state (which includes forwarding a RESET REQUEST packet to the DTE) and sending a RESET REQUEST packet to the XDCE (via the internetworking function).

Table J.11-7: XDCE Effect on DCE Restart States

	DCE Restart States (see Notes)		
Packet Received from XDCE	**PACKET LEVEL READY r1**	**DTE RESTART REQUEST r2**	**DCE RESTART REQUEST r3**
CALL REQUEST	See Table J.11-8	Send CLEAR REQUEST to internetworking process with D = 244	Send CLEAR REQUEST to internetworking process with D = 244
CALL ACCEPT, CLEAR REQUEST, DATA, INTERRUPT, INTERRUPT CONFIRMATION, RESET REQUEST	See Table J.11-8	A = DISCARD	A = DISCARD

Note: Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.

Table J.11-8: XDCE Effect on DCE Call Setup and Clearing States

	DCE Call Setup and Clearing States (see Note 5)						
Packet Received from XDCE	**READY p1**	**DTE CALL REQUEST p2**	**DCE CALL REQUEST p3**	**DATA TRANS-FER p4**	**CALL COLLISION p5**	**DTE CLEAR REQUEST p6**	**DCE CLEAR REQUEST to DTE p7**
CALL REQUEST	A = NORMAL S = p3 (forward)	INVALID	INVALID	INVALID	INVALID	INVALID	INVALID
CALL ACCEPT	A = DISCARD	A = NORMAL S = p3 (forward)	INVALID	INVALID	INVALID	A = DISCARD	A = DISCARD
CLEAR REQUEST	A = DISCARD	A = NORMAL S = p7 (forward)	A = NORMAL S = p7 (forward)	A = NORMAL S = p7 (forward)	INVALID	A = DISCARD	A = DISCARD
DATA, INTERRUPT, INTERRUPT CONFIRMATION or RESET REQUEST	A = DISCARD	INVALID	INVALID	See Table J.11-9	INVALID	A = DISCARD	A = DISCARD

Note: Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.

Table J.11-9: XDCE Effect on DCE Reset States

	DCE Reset States (see Notes)		
Packet Received from XDCE	**FLOW CONTROL READY d1**	**DTE RESET REQUEST d2**	**DCE RESET REQUEST to DTE d3**
RESET REQUEST	A = NORMAL S = d3 (forward)	A = NORMAL S = d1 (forward)	A = DISCARD
INTERRUPT	See Table J.11-10	A = DISCARD	A = DISCARD
INTERRUPT CONFIRMATION packet	See Table J.11-10	A = DISCARD	INVALID
DATA	A = NORMAL	A = DISCARD	A = DISCARD

Note: Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.

Table J.11-10: XDCE Effect on DCE Interrupt Transfer States

	DCE Interrupt Transfer States (see Notes)	
Packet Received from XDCE	**DTE INTERRUPT READY i1**	**DTE INTERRUPT SENT i2**
INTERRUPT CONFIRMATION	INVALID	A = Normal S = i1 (forward)

	DCE Interrupt Transfer States (see Notes)	
Packet Received from XDCE	**DTE INTERRUPT READY j1**	**DCE INTERRUPT SENT j2**
INTERRUPT	A = Normal S = j2 (forward)	INVALID

Note: Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates *that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.*

Table J.11-11: GNI (ANI) Effect on ADCE (GDCE) Packet Layer Ready States

Packet Received from GNI (ANI) (see Note 2)	**ADCE (GDCE) states (see Notes 1 and 3) PACKET LAYER READY r1**
Channel number zero	See Table J.11-12
Unassigned packet header	A = DISCARD
Call setup, call clearing, DATA, interrupt, flow control, or reset	See Table J.11-12

Note 1: The XDCE state is not necessarily the same state as the DTE/DCE interface

Note 2: All packets from the peer XNI have been checked for duplication before evaluation as represented by this state

Note 3: Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.

Table J.11-12: GNI (ANI) Effect on ADCE (GDCE) Call Setup and Clearing States

	ADCE (GDCE) Call Setup and Clearing States (see Notes 1, 7, and 8)					
Packet Received GNI (ANI) (See Note 2)	**READY p1**	**GNI (ANI) CALL REQUEST p2**	**ANI (GNI) CALL REQUEST p3**	**DATA TRANSFER p4**	**GNI (ANI) CLEAR REQUEST p6**	**ANI (GNI) CLEAR REQUEST to GNI (ANI) p7**
Format error (See Note 3)	A = ERROR (See Note 10) S = p7 D = 33 (See Note 9)	A = ERROR S = p7 D = 33 (see Note 6)	A = ERROR S = p7 D = 33 (see Note 6 & 9)	See Table J.11-13	A = ERROR S = p7 D = 25 (see Note 6)	A = DISCARD
CALL REQUEST	A = NORMAL S = p2 (forward request to DCE)	A = ERROR S = p7 D = 21 (see Note 6)	Not applicable (See Note 4)	Not applicable (See Note 4)	A = ERROR S = p7 D = 25 (see Note 6)	A = DISCARD
CALL ACCEPT	A = ERROR S = p7 D = 20 (See Note 10)	A = ERROR S = p7 D = 21 (see Note 6)	A= NORMAL S = p4 (forward to DCE) or A = ERROR S = p7 D = 42 (see Note 6)	A = ERROR S = p7 D = 23 (see Note 6)	A = ERROR S = p7 D = 25 (see Note 6)	A = DISCARD
CLEAR REQUEST	A = NORMAL S = p6 (do not forward)	A = NORMAL s = p6 (forward to DCE)	A = NORMAL s = p6 (forward to DCE)	A = NORMAL s = p6 (forward to DCE)	A = DISCARD	A = NORMAL S= p1 (do not forward)
CLEAR CONFIRMATION	A = ERROR S = p7 D = 20 (See Note 10)	A = ERROR S = p7 D = 21 (see Note 6)	A = ERROR S = p7 D = 22 (see Note 6)	A = ERROR S = p7 D = 23 (see Note 6)	A = ERROR S = p7 D = 25 (see Note 6)	A = NORMAL S = p1 (do not forward)
DATA, interrupt, flow control or reset packet	A = ERROR S = p7 D = 20 (see Notes 9 & 10)	A = ERROR S = p7 D = 21 (see Notes 6 & 9)	A = ERROR S = p7 D = 22 (see Notes 5 & 6)	See Table J.11-13	A = ERROR S = p7 D = 25 (see Note 6)	A = DISCARD

Note 1: The XDCE is not necessarily in the same state as the DTE/DCE interface.

Note 2: All packets from the peer XNI have been checked for duplication before evaluation as represented by this table.

Note 3: There are no detectable VDL Mode 3 format errors.

Note 4: The ADCE assigns all channel numbers used between the ANI and GNI, hence call collisions are not possible. When a CALL REQUEST by GNI packet is received bearing a temporary channel number associated with an SVC in the p4 state, the association of the temporary to permanent channel number is broken.

Note 5: Not applicable to the GNI

Note 6: The error procedure consists of performing the actions specified when entering the p7 state (including sending a CLEAR REQUEST packet to the peer XNI) and additionally sending a CLEAR REQUEST packet to the DCE (via the internetworking process).

Note 7: Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.

Note 8: The number in parentheses below an "A = NORMAL" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.

Note 9: An error condition is declared and transfer to the p7 state is possible only if the ground DTE address is known unambiguously. Otherwise the action is to discard the packet.

Note 10: The error procedure consists of performing the action when entering the p7 state (including sending a CLEAR REQUEST packet to the XNI) but without sending a CLEAR REQUEST packet to the local DCE.

Table J.11-13: GNI (ANI) Effect on ADCE (GDCE) Reset States

Packet Received from GNI (ANI) (See Note 2)	ADCE (GDCE) Reset States (see Notes 1, 4, and 5)		
	FLOW CONTROL READY **d1**	**GNI (ANI) RESET REQUEST** **d2**	**ADCE (GDCE) RESET REQUEST to GNI (ANI)** **d3**
RESET REQUEST	A = NORMAL S = d2 (forward to DCE)	A = DISCARD	A = NORMAL S = d1 (do not forward)
RESET CONFIRMATION	A = ERROR S = d3 D = 27 (see Note 3)	A = ERROR S = d3 D = 28 (see Note 3)	A = NORMAL S = d1 (do not forward)
INTERRUPT	See Table J.11-14	A = ERROR S = d3 D = 28 (see Note 3)	A = DISCARD
INTERRUPT CONFIRMATION	See Table J.11-14	A = ERROR S = d3 D = 28 (see Note 3)	A = DISCARD
DATA or flow control packet	See Table J.11-15	A = ERROR S = d3 D = 28 (see Note 3)	A = DISCARD
Format error	A = ERROR S = d3 D = 33 (see Note 3)	A = ERROR S = d3 D = 33 (see Note 3)	A = DISCARD

Note 1: *The XDCE is not necessarily in the same state as the DTE/DCE interface*

Note 2: *All packets from the peer XNI have been checked for duplication before evaluation as represented by this table.*

Note 3: *The error procedure consists of performing the specified actions when entering the d3 state (which includes forwarding a RESET REQUEST packet to the peer XNI) and sending a RESET REQUEST packet to the DCE (via the internetworking function).*

Note 4: *Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.*

Note 5: *The number in parentheses below an "A = NORMAL" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the* *received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*

Table J.11-14: GNI (ANI) Effect on ADCE (GDCE) Interrupt Transfer States

	ADCE/GDCE Interrupt Transfer States (See Notes 1, 3 & 4)	
Packet Received from GNI (ANI) (See Note 2)	**GNI (ANI) INTERRUPT READY i1**	**GNI (ANI) INTERRUPT SENT i2**
INTERRUPT	A = NORMAL S = I2 (forward to DCE)	A = ERROR S = d3 D = 44 (see Note 5)

	ADCE (GDCE) Interrupt Transfer States (see Notes 1, 3, & 4)	
Packet Received from GNI (ANI) (See Note 2)	**ADCE (GDCE) INTERRUPT READY j1**	**ADCE (GDCE) INTERRUPT SENT j2**
INTERRUPT CONFIRMATION	A = ERROR S = d3 D = 43 (see Note 5)	A = NORMAL S = j1 (forward confirmation to DCE)

Note 1: The XDCE is not necessarily in the same state as the DTE/DCE interface

Note 2: All packets from the peer XNI have been checked for duplication before evaluation as represented by this table.

Note 3: Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.

Note 4: The number in parentheses below an "A = NORMAL" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.

Note 5: The error procedure consists of performing the specified actions when entering the d3 state (which includes forwarding a RESET REQUEST packet to the peer XNI) and sending a RESET REQUEST packet to the DCE (via the internetworking function).

Table J.11-15: GNI (ANI) Effect on ADCE (GDCE) Flow Control Transfer States

	ADCE (GDCE) Flow Control Transfer States (see Notes 1, 5, and 6)	
Packet Received from GDLP (ADLP) (See Note 2)	**ADCE (GDCE) RECEIVE READY f1**	**ADCE (GDCE) RECEIVE NOT READY f2**
DATA packet with invalid PR (See Note 3)	A = ERROR S = d3 D =2 (see Note 7)	A = ERROR S = d3 D = 2 (See Note 7)
DATA packet with valid PR but invalid PS (See Note 4)	A = DISCARD Send REJECT with expected PS value	A = DISCARD but record expected PS value, send REJECT packet when busy condition ends
DATA packet with valid PR, PS	A = NORMAL (forward)	A = PROCESS, if possible; or A = DISCARD, but record PR value and send REJECT when busy condition ends

	ADCE (GDCE) Flow Control Transfer States (see Notes 1, 5, and 6)	
Packet Received from GDLP (ADLP) (See Note 2)	**ADCE (GDCE) RECEIVE READY g1**	**GNI (ANI) RECEIVE NOT READY g2**
RR, RNR, or REJECT packet with an invalid PR (See Note 3)	A = ERROR S = d3 D =2 (see Note 7)	A = ERROR S = d3 D = 2 (see Note 7)
RR packet with a valid PR (See Note 8)	A = NORMAL	A = NORMAL S = g1
RNR packet with a valid PR (See Note 8)	A = NORMAL S = g2	A = NORMAL
REJECT packet with a valid PR (See Note 8)	A = NORMAL	A = NORMAL S = g1

Note 1: The XDCE is not necessarily in the same state as the DTE/DCE interface

Note 2: All packets from the peer XNI have been checked for duplication before evaluation as represented by this table.

Note 3: An invalid PR value is one which is less than the PR value (modulo 16) of the last packet sent by the peer XNI, or greater than the PS value of the next data packet to be transmitted by the XNI.

Note 4: An invalid PS value is one that is different from the next expected value for PS.

Note 5: *Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.*

Note 6: *The number in parentheses below an "A = NORMAL" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*

Note 7: *The error procedure consists of performing the specified actions when entering the d3 state (which includes forwarding a RESET REQUEST packet to the peer XNI) and sending a RESET REQUEST packet to the DCE (via the internetworking function).*

Note 8: *RR, RNR, and REJECT packets have no end-to-end significance and are not forwarded to DCE.*

Table J.11-16: DCE Effect on ADCE (GDCE) Call Setup and Clearing States

	ADCE (GDCE) Call Setup and Clearing States (see Notes 1, 7 and 8)					
Packet Received from DCE (See Notes 2 & 4)	**READY p1**	**GNI (ANI) CALL REQUEST p2**	**ADCE (GDCE) CALL REQUEST p3**	**DATA TRANSFER p4**	**GNI (ANI) CLEAR REQUEST p6**	**ADCE (GDCE) CLEAR REQUEST p7**
CALL REQUEST (See Note 6)	A = NORMAL S = p3 (forward)	INVALID (See Note 5)	INVALID (See Note 3)	INVALID (See Note 3)	INVALID (See Note 3)	INVALID (See Note 3)
CALL ACCEPT (See Note 4)	A = DISCARD	A = NORMAL S = p4 (forward)	INVALID (See Note 3)	INVALID (See Note 3)	A = DISCARD	A = DISCARD
CLEAR REQUEST	A = DISCARD	A = NORMAL s = p7 (forward)	A = NORMAL s = p7 (forward)	A = NORMAL s = p7 (forward)	A = DISCARD	DISCARD
DATA, INTERRUPT, or RESET packets (See Note 4)	A = DISCARD	INVALID (See Note 3)	INVALID (See Note 3)	See Table J.11-17	A = DISCARD	A = DISCARD

Note 1: *The XDCE is not necessarily in the same state as the DTE/DCE interface*

Note 2: *This is the DTE packet received via the DCE after all DTE/DCE processing has occurred. Procedures local to the DTE/DCE interface (such as RR, RNR, and REJECT if in effect), do not affect the XDCE directly. All error procedures as documented in ISO 8208 have been performed. Hence* *certain packets are rejected by the interface and are not represented in this table.*

Note 3: *The DCE in its protocol operation with the DTE will detect this error condition, hence the erroneous packet can be said never to "reach" the XDCE; see also Note 2.*

Note 4: *The channel number for the DTE/DCE need not be the same channel number used for the ADCE/GDCE; a packet from the DTE which contains a channel number is associated with an air/ground channel by means of a previously established cross reference table. If none exists then the DTE/DCE channel by definition references an air/ground channel in the p1 state.*

Note 5: *The ADCE assigns all channel numbers used between the ANI and GNI; hence call collisions (denoted p5 ISO 8208) are not possible; see also Note 4.*

Note 6: *A CALL REQUEST from the DTE can never be associated with an XDCE channel number that is not in the p1 state.*

Note 7: *Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.*

Note 8: *The number in parentheses below an "A = NORMAL" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*

Table J.11-17: DCE Effect on ADCE (GDCE) Reset States

	ADCE (GDCE) Reset States (see Notes 1, 4 and 5)		
Packet Received from DCE	**FLOW CONTROL READY** **d1**	**GNI (ANI) RESET REQUEST** **d2**	**ADCE (GDCE) RESET REQUEST to GNI (ANI)** **d3**
RESET REQUEST	A = NORMAL S = d3 (forward)	A = NORMAL S = d1 (forward)	A = DISCARD
RESET CONFIRMATION	INVALID (See Note 3)	INVALID (See Note 3)	INVALID (See Note 3)
INTERRUPT	See Table J.11-18	A = DISCARD	Hold interrupt until VDL Mode 3 reset complete
INTERRUPT CONFIRMATION packet	See Table J.11-18	A = DISCARD	INVALID (See Note 3)
DATA (See Note 2)	A = NORMAL (forward)	A = DISCARD	Hold interrupt until VDL Mode 3 reset complete

Note 1: *The XDCE is not necessarily in the same state as the DTE/DCE interface.*

Note 2: *This is the DTE packet received via the DCE after all DTE/DCE processing has occurred. Procedures local to the DTE/DCE interface (such as RR, RNR, and REJECT if in effect), do not affect the XDCE directly. All error procedures as documented in ISO 8208 have been performed. Hence certain packets are rejected by the interface and are not represented in this table.*

Note 3: *The DCE in its protocol operation with the DTE will detect this error condition, hence the erroneous packet can be said never to "reach" the XDCE; see also Note 2.*

Note 4: *Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.*

Note 5: *The number in parentheses below an "A = NORMAL" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*

Table J.11-18: DCE Effect on ADCE (GDCE) Interrupt Transfer States

	ADCE (GDCE) Interrupt Transfer States (See Notes 1, 4, and 5)	
Packet Received from DCE (See Note 2)	**GNI (ANI) INTERRUPT READY i1**	**GNI (ANI) INTERRUPT SENT i2**
INTERRUPT CONFIRMATION	INVALID (See Note 3)	A = Normal S = i1 (forward)

	ADCE (GDCE) Interrupt Transfer States (See Notes 1, 4, and 5)	
Packet Received from XDCE	**DTE INTERRUPT READY j1**	**DCE INTERRUPT SENT j2**
INTERRUPT	A = Normal S = j2 (forward)	INVALID (See Note 3)

Note 1: *The XDCE is not necessarily in the same state as the DTE/DCE interface*

Note 2: *This is the DTE packet received via the DCE after all DTE/DCE processing has occurred. Procedures local to the DTE/DCE interface (such as RR, RNR, and REJECT if in effect), do not affect the XDCE directly. All error procedures as documented in ISO 8208 have been performed. Hence certain packets are rejected by the interface and are not represented in this table.*

Note 3: *The DCE in its protocol operation with the DTE will detect this error condition, hence the erroneous packet can be said never to "reach" the XDCE; see also Note 2.*

Note 4: *Table entries are defined as follows: A = action to be taken; S = the state to be entered; D = the diagnostic code to be used in packets generated as a result of this action; DISCARD indicates that the received packet is to be cleared from the XNI buffers; and INVALID indicates that the packet/state combination cannot occur.*

Note 5: *The number in parentheses below an "A = NORMAL" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*

Appendix K

CLNP Compression Definition

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K.1 Compression Formatting

CLNP compression shall be performed for all ATN ISO8473 CLNP packets received for transfer over the VDL Mode 3 system, unless the Network Initialization Parameter indicates no compression for CLNP packets, in which case, this appendix does not apply.

Note: Figure K-1 illustrates an uncompressed ATN CLNP packet.

<table>
<tr><th>Octet</th><th colspan="4">Field</th></tr>
<tr><td>1</td><td colspan="4">Network Layer Protocol Identifier</td></tr>
<tr><td>2</td><td colspan="4">Header Length Indicator = 82</td></tr>
<tr><td>3</td><td colspan="4">Version</td></tr>
<tr><td>4</td><td colspan="4">Lifetime</td></tr>
<tr><td>5</td><td>SP</td><td>MS</td><td>ER</td><td>Type</td></tr>
<tr><td>6</td><td colspan="4" rowspan="2">Segment Length</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td><td colspan="4" rowspan="2">Header Checksum</td></tr>
<tr><td>9</td></tr>
<tr><td>10</td><td colspan="4">Destination Address Length = 20</td></tr>
<tr><td>11</td><td colspan="4" rowspan="3">Destination Address</td></tr>
<tr><td>...</td></tr>
<tr><td>30</td></tr>
<tr><td>31</td><td colspan="4">Source Address Length = 20</td></tr>
<tr><td>32</td><td colspan="4" rowspan="3">Source Address</td></tr>
<tr><td>...</td></tr>
<tr><td>51</td></tr>
<tr><td>52</td><td colspan="4" rowspan="2">Data Unit Identifier</td></tr>
<tr><td>53</td></tr>
<tr><td>54</td><td colspan="4">Segment Offset</td></tr>
<tr><td>55</td><td colspan="4">(All Unix OS contain this field, even when zero)</td></tr>
<tr><td>56</td><td colspan="4" rowspan="2">Total Length</td></tr>
<tr><td>57</td></tr>
<tr><td>58</td><td colspan="4">Priority Type</td></tr>
<tr><td>59</td><td colspan="4">Priority Length = 1</td></tr>
<tr><td>60</td><td colspan="4">Priority Value</td></tr>
<tr><td>61</td><td colspan="4">Security Type</td></tr>
<tr><td>62</td><td colspan="4">Security Length = 17</td></tr>
<tr><td>...</td><td colspan="4">Security Values</td></tr>
<tr><td>79</td><td colspan="4">Security Values</td></tr>
<tr><td>80</td><td colspan="4">QOS Type</td></tr>
<tr><td>81</td><td colspan="4">QOS Length = 1</td></tr>
<tr><td>82</td><td colspan="4">QOS Value</td></tr>
</table>

Figure K-1: ATN CLNP Packet

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K.1.1 Compression Header Definition

Figure K-2 illustrates the CLNP header compression format which shall be used.

<table>
<tr><th>Bit</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th></th><th></th></tr>
<tr><td>Octet 0</td><td colspan="4">Payload</td><td colspan="4">Compression Type</td><td rowspan="4">Short</td><td rowspan="17">Long</td></tr>
<tr><td>Octet 1</td><td>Q</td><td colspan="7">Index Number</td></tr>
<tr><td></td><td colspan="4">QOS</td><td colspan="4">Priority</td></tr>
<tr><td></td><td colspan="8">Security</td></tr>
<tr><td></td><td>S</td><td>E</td><td>M</td><td>T</td><td>H</td><td>O</td><td>L</td><td>D</td><td rowspan="13"></td></tr>
<tr><td></td><td colspan="8">Lifetime (H)</td></tr>
<tr><td></td><td colspan="8" rowspan="2">Data Unit Identifier (S)</td></tr>
<tr><td></td></tr>
<tr><td></td><td colspan="8" rowspan="2">Segment Offset
(O)</td></tr>
<tr><td></td></tr>
<tr><td></td><td colspan="8" rowspan="2">Total Length (L)</td></tr>
<tr><td></td></tr>
<tr><td></td><td colspan="8" rowspan="2">Discard Reason (D - ER)
(Error PDU only)</td></tr>
<tr><td>Octet n</td></tr>
<tr><td>Octet n+1</td><td colspan="8">Options Length</td></tr>
<tr><td>Octet n+2</td><td colspan="8" rowspan="3">Options</td></tr>
<tr><td>...</td></tr>
<tr><td>Octet p</td></tr>
</table>

Figure K-2: Compressed CLNP Header Format

> Note: *The first octet, containing the payload and compression type, is sent for all network packet types and strictly speaking is not part of the CLNP compressed header. (Figure K-2 shows this octet as octet 0). As this octet contains fields which depend on the compression state, it is convenient to represent them in Figure K-2 and to define its meaning at the same time.*

There are 2 types of compressed packets. A short packet header shall end with the Security field. A short packet shall contain the Payload, Compression Type, Q field, Index Number, QOS, Priority and Security fields. A long packet header shall begin with the same information as the short packet, followed by a Bit Field. Settings in this Bit Field shall determine the presence of the remaining field types. (For example, when the S field is true (S = 1), the Data Unit Identifier is present.) The remaining fields shall appear in the order shown in Figure K-2.

The compressed CLNP packet header fields shall be as defined in the following sections.

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K.1.1.1 Payload

Shall be as defined in Section 3.3.3.1, Figure 3-10.

K.1.1.2 Compression Type

Shall be as defined in Figure K-3.

Bit	Meaning
0000	TYPE_CLNP
0001	TYPE_RESTART
0010	TYPE_UNCOMPRESSED_CLNP
0011	TYPE_COMPRESSED_CLNP_LONG_WITH_OPTIONS
0100	TYPE_COMPRESSED_CLNP_LONG_NO_OPTIONS
0101	TYPE_COMPRESSED_CLNP_SHORT
0110	TYPE_MULTICAST
0111	Reserved
1000-1111	Reserved

Figure K-3: Compression Field (Type-Specific Information Field) Definition for ISO8473 (Payload Field Value of 0001 Binary)

K.1.1.3 Q

Shall indicate the presence of QOS information. If not set (Q=0), no QOS option shall be contained in the original packet.

K.1.1.4 Index Number

The Index Number shall be changed for each NSAP pair. The Index Number shall have a range of 0 to 127. If there are no index numbers left, an Index Number which has not been used for CT3 minutes (System Parameter) shall be used (i.e., reassigned). If no reassignable indexes are available, the packet shall be sent as uncompressed.

K.1.1.5 QOS

The QOS field shall consist of the CE, T/C, E/T, E/C bits in the order listed. The sequencing vs. transit delay (S/T) bit shall be sent in the T field (see Figure K-4). Whenever the S/T bit is set, only a long compression format shall be used.

K.1.1.6 Priority

The Priority field shall be set to the low order 4 bits of the priority option value of the ATN CLNP packet. When the priority option is not present, the Priority field shall be set to all 1s (hexadecimal F).

K.1.1.7 Security

The Security field shall be subdivided into two fields and shall indicate the security parameter of an ATN CLNP packet: the traffic type security tag, consisting of the 5 high order bits and the security classification tag, consisting of the low order 3 bits. If no security option is present (or only one security value is present), the missing field(s) shall be coded as zero.

K.1.1.8 Bit Field

The Bit Field, as well as the Q bit of Section K.1.1.3, shall be as defined in Figure K-4.

Bit	Meaning (Present = 1)
Q	QOS Options Present
S	SP flag of CLNP Header - Data Unit Identifier Present
E	Complement of CLNP Error Flag (ER) flag
M	More Segments (MS) bit of CLNP Header
T	Sequence vs. Transit Delay Bit (from QOS Option)
H	Lifetime Field present (Hop Count)
O	Segment Offset Present
L	Total Length field present
D	Type of PDU (Error = 1, Data = 0)

Figure K-4: Bit Field Definitions

K.1.1.9 Lifetime

The Lifetime field shall not be sent if its value for downlinks is greater than hexadecimal 1c; or for uplinks its value is greater than 5. The presence of the Lifetime field shall be indicated by the H bit.

K.1.1.10 Data Unit Identifier(DUI)

The Data Unit Identifier shall always be sent for segmented packets or whenever the SP bit is set. Its presence shall indicate that the compressed packet represents a segmented packet. The presence of DUI field shall be indicated by the S bit.

K.1.1.11 Segment Offset

The Segment Offset shall be sent whenever the Segmentation Permitted (SP) bit is set and the Segment Offset is greater than zero. The presence of the Segment Offset field shall be indicated by the O bit.

K.1.1.12 Total Length

The Total Length field shall be sent whenever a new DUI is set, i.e., for each new fragment. On subsequent fragments for the same DUI the field need not be sent. The presence of the Total Length field shall be indicated by the L bit.

K.1.1.13 Discard Reason

If the packet is an error PDU (D = 1), the Discard Reason in the error PDU shall be copied into this location.

K.1.1.14 Options Length

An Options Length field shall precede the Options field indicating the number of bytes occupied by the Options field.

K.1.1.15 Options

Any remaining options after the QOS, Priority, and Security options have been removed shall be appended in this location.

> Note: *Two types of long packets are used to signal the decompressor to process the options fields. Otherwise, the options would be interpreted as user data.*

K.1.2 Compression Field Values

Figure K-3 defines the compression field values of the Type-Specific Information subfield of Figure 3-10 when the payload is an ISO8473 CLNP packet. The use of this field shall be as defined in the sections on compression and decompression rules.

K.1.2.1 Multicast Packets

The TYPE_MULTICAST shall be a short compressed packet. NSAPs may be predefined or dynamically defined when using multicast packets. Predefined NSAPs shall be determined using the index number of the compressed short packet. When operating in multicast mode using predefined packet types, the TYPE_UNCOMPRESSED_CLNP packet shall never be used, as the index to NSAP cross-reference is already known. When using dynamically defined NSAPs for multicast packets a TYPE_UNCOMPRESSED_CLNP initialization packet with the multicast NSAPs shall be sent.

> Note: *An example of the use of TYPE_MULTICAST is a weather broadcast having a destination NSAP which indicates all hosts who want weather information, and a source NSAP indicating that the data originates from a CAA weather processor.*

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K.1.2.2 Uncompressed CLNP Packets

A type TYPE_UNCOMPRESSED_CLNP packet shall be the original CLNP packet sent with the first byte replaced by the index number assigned to this CLNP packet.

K.1.2.3 Restart Packets

On reception of a restart packet all index numbers that have been assigned by the receiving entity, and the information referenced by the index numbers, (e.g., NSAP pair) shall be deleted. For a ground VDL Mode 3 installation deletion shall be restricted to the index information associated with the aircraft originating the restart packet.

> Note: *A compressor has two sets of index numbers. Those assigned by the compressor and those assigned by its peer. Reception of a restart packet only applies to the index numbers used for decompressing, i.e., the index numbers assigned by the remote peer.*

K.2 Compression Rules

- All ISH packets shall be sent as TYPE_CLNP.

> Note: *The following compression and decompression rules are for both the air and ground VDL Mode 3 equipment. It is assumed that both require broadcast compression (although the usefulness of aircraft VDL Mode 3 broadcasting has yet to be determined).*

- If the CLNP version field is not 1, the packet shall be sent as TYPE_CLNP.

- If the CLNP packet is of any type other than Data or Error, the packet shall be sent as TYPE_CLNP.

> Note: *It has now been determined that this packet is suitable for compression.*

- If the NSAP pair has not been associated with an index number, the CLNP packet shall be sent as TYPE_UNCOMPRESSED_CLNP.

- If the link is simplex, the packet is not TYPE_MULTICAST, and the last CT1 (System Parameter) packets for this index/pair association have been sent as compressed type, or CT2 (system parameter) seconds have passed since the last packet with this index number has been sent, the packet shall be sent as TYPE_UNCOMPRESSED_CLNP.

- If the security option is not coded as specified for ATN traffic, the CLNP packet shall be sent as TYPE_COMPRESSED_CLNP_LONG_WITH_OPTIONS. The security and other non-compressed options shall be copied into the options portion of the compressed header.

- If the priority option is present with a value greater than 14, the CLNP packet shall be sent as TYPE_COMPRESSED_CLNP_LONG_WITH_OPTIONS. The priority and other non-compressed options shall be copied into the options portion of the compressed header.

- If the CLNP packet SP bit is zero, the lifetime field has a value of greater than hexadecimal 1c on downlinks or is less than 5 on uplinks, the S/T bit is not set, the packet type is DT, the ER bit is non-zero, and no options are present other than QOS, Security, or Priority, the packet shall be sent as TYPE_COMPRESSED_SHORT.

  Note 1: Many CLNP installations include the segment information fields even when the packet is unsegmented. It is thus necessary to check for this condition.

  Note 2: At this point, the packet compression type must be long.

- If a CLNP option is present which is not QOS, security, priority, or padding, the packet shall be sent as TYPE_COMPRESSED_CLNP_LONG_WITH_OPTIONS. The options shall be copied into the options portion of the compressed header.

- Otherwise the packet shall be sent as TYPE_COMPRESSED_CLNP_LONG_NO_OPTIONS

For the compressed long packets, the Lifetime field shall be included when its value is greater than 5, or less than hexadecimal 1d. The DUI field shall be included when the packet is segmented. The Segment Offset field shall be included when it is non-zero and the SP bit from the CLNP header is set. The Total Length field shall be included if this is the first time this DUI is being compressed. The Options fields that are not QOS, priority, security, or padding shall be included unmodified. The T, M, and S fields shall be set to the corresponding values of the S/T, MS and SP values in the original packet. The E fields shall be set to the inverse (complement) of the ER value. The Discard Reason field shall be set if the packet is an Error PDU.

K.3 Decompression Rules

- Upon receipt of a TYPE_UNCOMPRESSED_CLNP packet, the index number and NSAP information shall be recorded. The Network Layer Protocol ID shall be restored.

- Upon receipt of a TYPE_COMPRESSED_CLNP packet (long or short), if the index number is not associated with an NSAP pair and the link is duplex, a restart of the remote compressor shall be signaled by setting the payload field to TYPE_RESTART. When this occurs, subsequent fields need not be sent if no data is available for transfer. The lack of subsequent fields shall be determined by a link layer length of 1 octet. If the link is simplex, then all packets with the undefined index shall be discarded, until a packet refresh is sent. Optionally, the packets can be held until the refresh and then decompressed.

- Upon receipt of a TYPE_COMPRESSED packet (Long or Short), the Network Layer Protocol field shall be set to 81.
- If the packet is of TYPE_COMPRESSED_SHORT or TYPE_MULTICAST, or the H bit is not true, the Lifetime field shall be set to hexadecimal 1d on the ground, 5 in the air. Otherwise, the Lifetime field shall be set to that contained in the compressed header.
- The ER bit shall be set to non-zero and the MS and SP bits to zero for the TYPE_COMPRESSED_SHORT packet. Otherwise, the MS and SP flags shall be set as indicated in the M and S bits, and the ER bit shall be set to the compliment of the E bit value.
- The Type field shall be set to DT for packets of TYPE_COMPRESSED_SHORT or TYPE_MULTICAST. Otherwise, the D field shall be checked to determine the Type field value.
- The Segment Length shall be calculated based on frame length information from the link layer and the additional information from decompression.
- The checksum shall be recalculated once the header has been reconstructed.
- The NSAP fields shall be set to those as previously recorded for the index value.
- If the packet is of TYPE_COMPRESSED_SHORT or TYPE_MULTICAST, or the S field is not true in a TYPE_COMPRESSED_CLNP_LONG_NO_OPTIONS or TYPE_COMPRESSED_CLNP_LONG_WITH_OPTIONS packet, then the DUI, Segment Offset and Total Length fields shall not be present. Otherwise, the DUI field shall be set to that contained in the compressed header. If the O bit is set, the Segment Offset shall be set to the field included; otherwise, it shall be set to 0. If the L bit is set, the Total Length field shall be recorded for use in future packets having the same Index/DUI pair and copied into the decompressed header.
- If the Total Length field is not sent, it shall be set to that recorded for this Index/DUI pair. If there is no stored value then all segments with this DUI shall be discarded. Optionally a refresh packet may be requested.
- If the Q bit is set, the QOS options field shall be reconstructed using the information in the QOS field and the S/T bit.

- If the security octet is non-zero the security options field shall be reconstructed based on the information provided.

- If the priority nibble is not equal to Hex F, the priority option shall be reconstructed based on the information provided.

- It is permissible to add padding fields within the options section for octet alignment purposes when reconstructing the packet.

K.4 Compression System Parameters

The parameters used by the CLNP compression shall be as listed in Figure K-5. The CLNP compression parameters shall be determined by GNI transfer to the aircraft VDL VDL Mode 3 system using the Network Initialization XID parameter in a CTRL frame, if the default values are not to be used. These parameters shall be transferred using the Network Initialization parameter of Section 3.3.2.3.3.3.4.1.3. These parameters shall take the place of the subparameter ID, length, and value fields defined in Table 3-72a, with the Network Type field indicating hexadecimal 01.

Symbol	Parameter Name	Minimum	Maximum	VDL Mode 3 Default	Increment
CT1	Multicast Packet Period	1	255	5	1 packet
CT2	Multicast Refresh Timer	1	32000	180	1 second
CT3	Index Idle Timer	1	32000	20	1 minute

Figure K-5: CLNP Compression System Parameters

K.4.1 CT1 (Multicast Packet Period) Parameter

The Multicast Packet Period defines the period whereby an uncompressed packet is sent to refresh the compressor state for the receiving unit. The XID format for CT1 shall be defined in Table K-6.

Table K-6: CT1 Parameter

Parameter ID	0 1 0 1	0 0 1 0	Multicast Packet Period
Parameter Length	0 0 0 0	0 0 0 1	
Parameter Value	$v_8\ v_7\ v_6\ v_5$	$v_4\ v_3\ v_2\ v_1$	

K.4.2 CT2 (Multicast Refresh) Timer

The Multicast Refresh Timer sets an upper bound to the time between transmission of uncompressed headers in case message traffic is light. This ensures the receiver can correlate the header with the compression index in a timely fashion. The XID format for CT2 shall be defined in Table K-7.

Table K-7: CT2 Timer

Parameter ID	0 1 0 1	0 0 1 1	Multicast Refresh Timer
Parameter Length	0 0 0 0	0 0 1 0	
Parameter Value	v_{16} v_{15} v_{14} v_{13}	v_{12} v_{11} v_{10} v_9	
	v_8 v_7 v_6 v_5	v_4 v_3 v_2 v_1	

K.4.3 CT3 (Index Idle) Timer

The Index Idle Timer places an upper bound on how long the compressor should wait before recovering an idle index. An index is assumed idle if no message traffic has passed using it before the CT3 timer expires. The XID format for CT3 shall be defined in Table K-8.

Table K-8: CT3 Timer

Parameter ID	0 1 0 1	0 1 0 0	Index Idle Timer
Parameter Length	0 0 0 0	0 0 0 1	
Parameter Value	v_{16} v_{15} v_{14} v_{13}	v_{12} v_{11} v_{10} v_9	
	v_8 v_7 v_6 v_5	v_4 v_3 v_2 v_1	

K.5 Compression Initialization

K.5.1 Aircraft Installations

Whenever a leave message is generated or a system power-up occurs, all dynamically assigned index information shall be deleted.

K.5.2 Ground Installations

Whenever a leave message is generated, indicating data link communication to a particular aircraft is no longer possible, all dynamically assigned index information related to that aircraft shall be deleted. Whenever a system power-up condition occurs, all dynamically assigned index information for all aircraft shall be deleted.

--END

Appendix L

Preparation of Link Budgets for VHF Data Link

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1. Introduction

The fundamental determinant of the performance of radio communications systems, of which all variations of VHF Data Link (VDL) are examples, is the RF link. For any radio link, the achieved signal-to-noise ratio (SNR) determines the quality of the received signal. For radio systems using digital transmission techniques, which include VDL variants, the signal quality is normally expressed in terms of bit error rate (BER) or the word error rate (WER), both of which are related to SNR by well-known formulations. In turn, the BER achieved on a communications link, working in conjunction with the processing design features of the system, directly affects the Installed Communications Performance (ICP) parameters of delay and integrity. The performance margin designed into a link— that is, the difference between the actual SNR achieved under nominal conditions and the minimum required SNR— directly affects the link availability parameter, which may be a significant part of the overall system availability quantified in the ICP.

The basic relationships of these attributes are relatively straightforward and construction of link budgets is detailed in a number of classical texts on communications engineering, such as [4] [5] and [6] However, the interactions of such factors as propagation anomalies of the RF path, interference and the design features of different systems can be difficult to analyze consistently. Consequently, this appendix sets out the methodology by which the *pro-forma* tables and requirements detailing the MASPS requirements have been developed.

The appendix begins by identifying the key equations that are commonly used to make link margin calculations and the assumptions that are commonly made. A set of standard assumptions is set forth, and the link margins based on those assumptions are tabulated. With the background presented in this appendix, the tabulated link budgets can provide insight into the various tradeoffs involved in establishing the system performance.

2. Link Budget Analysis

2.1 Propagation Effects

The received signal level on VHF line-of-sight paths is given by

$$\begin{aligned} P_R &= \frac{P_T G_T G_R \lambda^2}{L_T L_R (4\pi\rho)^2} \times C \\ &= P_T \times \left(\frac{G_T}{L_T}\right) \times \left(\frac{G_R}{L_R}\right) \times \left(\frac{\lambda}{4\pi\rho}\right)^2 \times \frac{1}{L_{GR}} \end{aligned} \qquad [L.1]$$

where P_R and P_T are the received and transmitted power respectively, G_R and G_T are the receive and transmit antenna gain respectively, L_R and L_T are the receive and transmit line losses respectively, λ is the wavelength, and L_{GR} is the squared magnitude of a complex-valued term that accounts for interference between the direct line-of-sight and ground reflection paths.

The factor $\left(\frac{\lambda}{4\pi\rho}\right)^2$ is the free-space propagation loss, which may be expressed in decibels as

$$L_{FS} = 37.8 + 20\log_{10}(\rho) + 20\log_{10}(f) \qquad [L.2]$$

where L_{FS} is the free-space loss[3] in decibels, ρ is line-of-sight distance (slant range) between the transmitter and receiver in nautical miles, and f is the operating frequency in Megahertz. For the link budgets presented in the MASPS and in this appendix, the worst-case value of $f = 137$ MHz is always used.

The term L_{GR} accounts for the combined effects of reflection from the Earth's surface and the dependence of the atmosphere's refractive index on aircraft altitude. These effects have been modeled in the Johnson-Gierhart model. The value of C can also be estimated by assuming that signals propagate between the ground and the aircraft, between the ground station and the specular point, and between the specular point and the aircraft in a straight line. This would be the case only if the refractive index of the lower atmosphere were constant. In reality, the refractive index of the lower atmosphere decreases with height above the surface of the Earth, due to the decrease in temperature. The monotonically decreasing refractive index causes the radiowave path to bend downward (refract) as the signal propagates. This simple ray-tracing model results in a closed-form expression for L_{GR}

$$\frac{1}{L_{GR}} = \left| e^{j2\pi\rho/\lambda} + \Gamma e^{j2\pi(r_1+r_2)/\lambda} \right|^2 \qquad [L.3]$$

where ρ is the line-of-sight distance between the ground station and the aircraft, r_1 is the distance from the ground facility to the specular[4] reflection point, r_2 is the distance from the specular reflection point to the aircraft, and Γ is the reflection coefficient at the "specular reflection" point. Γ is a complex-valued function of the angle of reflection, antenna polarization and ground conductivity. Through mathematical transformations, it can be shown that straight paths can be assumed for the line-of-sight and reflected radiowave paths provided one uses a modified or "effective Earth radius" in the calculation of the distances r_1 and r_2 to the "specular ground reflection" point, and thence in computation of ρ. The calculation of the ground reflection loss for very long paths is the key concern of these link budgets. In this case, the angle of reflection, γ, of the reflected radiowave is near grazing, and the magnitude of the reflection coefficient Γ is, for all practical purposes, equal to –1 for both horizontal and vertical polarization and all values of ground conductivity (see [3] Section 2.3(b) *et seq.*). In this case setting $\Gamma = -1$ in [L.3], and taking the log of the term in brackets to arrive at the loss in decibels, the ground reflection loss reduces to

---

[3] In keeping with traditional usage, a *loss*, given as a positive number in decibels, is the negative of the equivalent *gain*, expressed in decibels. Therefore, in the link budget, losses will be subtracted and gains will be added.

[4] The specular reflection point is defined as the point at which the angle of incidence of the reflected radiowave equals the angle of reflection. Hence, this point is determined strictly from geometrical considerations given the height of the ground station antenna, the aircraft flight level and the radius of the Earth.

$$\left[L_{GR}\right]_{dB} = -20\log_{10}\left(\left|2\sin\left(\pi\frac{(r_1 + r_2 - \rho)}{\lambda}\right)\right|\right) \qquad [L.4]$$

where the distances r_1, r_2 and ρ must be calculated using a spherical Earth geometry with "effective Earth radius", A_{EFF}, given by

$$A_{EFF} = \kappa A \qquad [L.5]$$

where A is the actual Earth radius, which is equal to 6,378 km and κ is the "effective Earth radius factor" which accounts to climatic effects that affect the height dependence of the refractive index of the lower atmosphere. The values of r_1, r_2 and ρ are computed by means of the techniques given in [3]

Whether computed from the Johnson-Gierhart model or by the simpler ray-tracing technique described by [L.4], the value of L_{GR} is included in the link budgets as an "excess path loss" or "ground reflection loss". This loss results from interference between a signal that propagates in a straight line from the ground station to the aircraft and a signal that travels from the ground station to the aircraft by way of a "specular reflection" point on the surface of the Earth. It is obvious from [L.4] that when the path difference is equal to $\lambda/2$ (about 1 meter for VHF frequencies), the value of L_{GR} can be –6 dB, i.e. the signal is *enhanced* by constructive interference.

The "effective Earth Radius" factor accounts for the variations in path loss when all other factors, such as transmit power, antenna gains, antenna heights and distances, remain fixed. Therefore, when calculating link margins it is important that the long-term variations in refractive index be accounted properly. Through many years of measurements it has been determined that the median value of the effective Earth radius factor is $\kappa = \frac{4}{3}$. This is a median value, that is, 50 % of the time the effect will be increased loss and 50% of the time the effect will be decreased loss, regardless of the path length. The variations in κ about the median *are* path length dependent, with the smallest values of κ being the ones that represent worst case conditions (largest reflection loss). For short paths (10 nmi) in continental temperate climates such as Europe and parts of North America, κ can be as small as $\kappa = 0.7$, while for very long paths (>100 nmi), the smallest values of κ recorded are $\kappa = 1$. Additional detail may be found in references [1] and [2].

The variation in κ is smaller when observed for longer paths, because κ represents an average of the height variation in refractive index along the path.

The longer the path, the more averaging of extreme gradients occurs. Unfortunately there is no data for paths longer than 100 nmi. Therefore in order to determine the worst case "excess path loss" or "ground reflection loss" for the extreme 160 nmi to 200 nmi paths we are interested in, we are forced to use $\kappa = 1$, although the trends in the data reported in [1] indicates that this may be pessimistic.

In comparison to this ray-tracing approach, which uses the effective Earth radius to model real-world effects, the Johnson-Gierhart model provides a percentile-based estimate of the excess path loss. The link budgets contained in the main body of the MASPS use the Johnson-Gierhart results at the 95th percentile. For a 200 nmi path length, and an aircraft elevation of 33,000 feet, the Johnson-Gierhart 95th percentile results are comparable to those achieved by ray-tracing with an Earth radius factor of $\kappa = 1.27$.

Table L-1 shows the free space path loss and ground reflection (excess) loss ~~as a~~ for several extreme values of the range, ρ, between the VDL ground station and the airborne VDL receiver. The table provides results using both the ray-tracing and Johnson-Gierhart methods. The excess loss values are presented assuming aircraft flight level altitudes of 33,000, 45,000 and 70,000 feet, and ground station antenna heights of 33 ft and 50 ft. In Table L-1, the Ground Reflection Loss assumes a smooth spherical Earth with effective Earth radius factor $\kappa = \frac{4}{3}$, which applies when median (50% percent of the time) refractive propagation conditions exist. As expected, the median ray-tracing results are more optimistic, i.e. less excess path loss, than the 95th percentile Johnson-Gierhart predictions.

Table L-1: Free Space and Ground Reflection Loss vs. Range, Aircraft Flight Level and Ground Antenna Height, (Median refractive conditions or effective Earth radius factor κ = 4/3)

Range (nmi)	FS Loss (dB)	Smooth Earth Ground Reflection Loss (dB) by ray tracing						Johnson-Gierhart
		Gnd Ant. Height = 33 ft			Gnd Ant. Height = 50 ft			
		33,000 ft	45,000 ft	70,000 ft	33,000 ft	45,000 ft	70,000 ft	33,000 ft
160	124.6	0.7	-3.4	-6.0	-2.4	-5.6	-2.7	4.0
180	125.6	4.4	-1.3	-5.7	0.9	-4.2	-5.4	n/a
200	126.6	10.0	1.4	-4.7	6.4	-1.9	-6.0	11.9

Table L-2 presents the worst-case sub-refractive propagation conditions, where the effective Earth radius factor is $\kappa = 1$. These values are again compared with the Johnson-Gierhart model results. Except for the aircraft altitude of 70,000 feet, the ray-tracing results are more pessimistic; that is, they predict a greater loss. This is to be expected, because the $\kappa = 1$ is widely regarded as a worst-case condition for these propagation distances, as compared with the 95th percentile nature of the Johnson-Gierhart predictions.

Table L-2: Free Space and Ground Reflection Loss vs. Range, Aircraft Flight Level and Ground Antenna Height (Worst case sub-refractive conditions or effective Earth radius factor $\kappa = 1$)

Range (nmi)	FS Loss (dB)	Smooth Earth Ground Reflection Loss (dB) by ray tracing						Johnson-Gierhart
		Gnd Ant. Height = 33 ft			Gnd Ant. Height = 50 ft			
		33,000 ft	45,000 ft	70,000 ft	33,000 ft	35,000 ft	70,000 ft	33,000 ft
160	124.6	4.2	-1.9	-5.9	0.8	-4.6	-4.5	4.0
180	125.6	12.3	1.5	-5.0	8.6	-1.8	-6.0	n/a
200	126.6	134.4	6.7	-3.4	132.6	3.1	-5.6	11.9

2.2 Noise Figure Computations

Evaluation of [L.1] establishes the signal level at the receiver input. The error performance of the link is determined by the ratio of the average received power to the average noise power, that is, by the signal-to-noise ratio. This requires that we estimate the amount of noise present in the receiver signal processing bandwidth. The techniques for computing the amount of noise are well known. A detailed explanation may be found in [4]

The noise power spectral density, N_0, is related to an *equivalent noise temperature*, ΔT, and the associated *noise figure*, F, by

$$\begin{aligned} N_0 &= kT = k(T_0 + \Delta T) \\ \Delta T &= T_0(F-1) \end{aligned} \qquad [L.6]$$

where $T_0 = 290\ \mathrm{K}$, and k is Boltzmann's constant. In a cascade of M cascaded elements, such as that illustrated in Figure L-1, the total system noise temperature, referenced to the input terminal at Point A is given by

$$T_{SYS} = T_{IN} + T_0(F_1 - 1) + \frac{T_0(F_2 - 1)}{G_1} + \frac{T_0(F_3 - 1)}{G_1 G_2} + \cdots + \frac{T_0(F_M - 1)}{G_1 G_2 G_3 \cdots G_{M-1}} \qquad [L.7]$$

where G_n and F_n represent the power gain and noise figure of the *n-th* stage in the cascade, respectively, and T_{IN} is the noise temperature of sources external to the cascaded system.

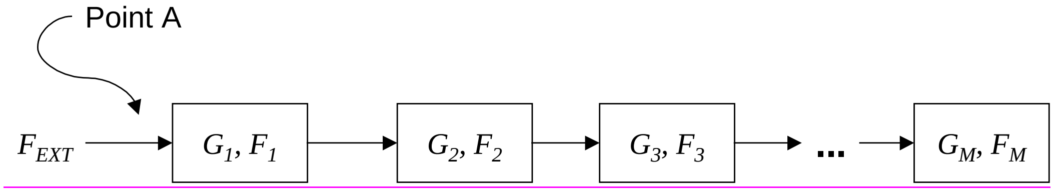

Figure L-1: System of Cascaded Elements

The system noise temperature computed by [L.7] may be referenced to other points along the cascade, as desired, by multiplying the result of [L.7] by the total gain prior to the desired reference point. That is, the noise temperature referenced to the input to the second element is

$$T_{SYS}\Big|_{\text{INPUT TO SECOND BLOCK}} = G_1\, T_{SYS}\Big|_{\text{POINT A}} \tag{L.8}$$

For the VDL system, there are two elements in the cascade: the VDL receiver and the cable loss between the antenna and receiver input. The resultant cascade is shown in Figure L-2. The receiver is described by its noise figure, F_{RECV}.[5] The cable loss is described by

$$\begin{aligned} G_R &= \frac{1}{L_R} \\ F_R &= L_R \end{aligned} \tag{L.9}$$

where the value of L_R is the same used in [L.1].

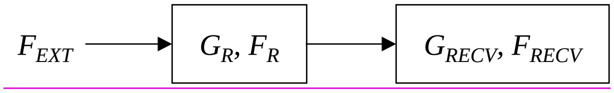

Figure L-2: VDL Cascaded Noise Model

For the VDL system defined in the MASPS, the input noise temperature is determined by the external noise figure, F_{EXT}.

$$T_{IN} = T_0 + T_0(F_{EXT} - 1) \tag{L.10}$$

Applying [L.7], [L.8], [L.9], and [L.10], the system noise temperature and noise power spectral density referenced to the receiver input are

$$\begin{aligned} T_{SYS}\Big|_{\text{RECEIVER INPUT}} &= \frac{T_0}{L_R} \times \left[F_{EXT} + (L_R - 1) + L_R(F_{RECV} - 1)\right] \\ N_0\Big|_{\text{RECEIVER INPUT}} &= \frac{kT_0}{L_R} \times \left[F_{EXT} + (L_R - 1) + L_R(F_{RECV} - 1)\right] \end{aligned} \tag{L.11}$$

For the VDL link budgets of the MASPS and this appendix, the external noise figure is assumed to be generated by man-made noise.

If the receiver is considered as a standalone block, the noise power spectral density is computed by applying [L.6]:

$$N_0\Big|_{\text{RECEIVER ALONE}} = k\left[T_0 + T_0(F_{RECV} - 1)\right] = kT_0F_{RECV} \tag{L.12}$$

---

[5] Because the receiver is the last element in the cascade, the receiver gain plays no role in [L.7], and is not required for this computation.

2.3 Required Signal-to-Noise Ratio

The relationships between channel modulation, channel coding techniques and the bit error rate or word error rate that can be achieved are complex.

$$\left(\frac{E_S}{N_0}\right)_{REQD} = \left(\frac{E_{CB}}{N_0}\right)_{THEORY} \times R_C \times L_{IMP} \times L_{RC} \qquad [L.13]$$

where E_S is the energy per channel symbol, E_{CB} is the energy per channel bit, R_C is the number of channel bits in each channel symbol, L_{IMP} is the loss due to imperfect implementation of the transmitter modulator and receiver demodulator, and L_{RC} is the loss associated with the raised cosine filter defined for VDL. To establish the receiver design requirements, the assumption is that the receiver is a stand-alone block; therefore, N_0 is computed by means of [L.12]. The energy per channel symbol is given by

$$E_S = \frac{P_R}{D} = P_R T_C \qquad [L.14]$$

where P_R is the received signal power, computed by means of [L.1], D is the rate at which channel symbols are transmitted, in symbols/second, and T_C is the symbol duration, measured in seconds. P_R is generally given in either watts or milliwatts, whichever is more convenient.

For the Differentially Encoded Eight Phase Shift Keying (D8PSK) used for VDL Mode 2 and VDL Mode 3, [5] gives the probability of a channel symbol error, P_E, as

$$P_E = \operatorname{erfc}\left(\frac{E_S}{N_0\sqrt{1+2\frac{E_S}{N_0}}}\sin\frac{\pi}{8}\right) \qquad [L.15]$$

which holds for values of $E_S / N_0 > 5\text{ dB}$.

Each symbol carries three bits of information, so the approximate bit error rate is:

$$P_B \approx \frac{1}{\log_2(8)} P_E = \frac{1}{3} P_E \qquad [L.16]$$

Using the definition $\operatorname{erfc}(x) = \frac{2}{\sqrt{\pi}}\int_x^\infty e^{-t^2}dt$, the value of E_S / N_0 required to sustain a channel bit error rate of 10^{-3} is 17.8 dB. This corresponds to a value of E_{CB} / N_0 of 13.0 dB, as assumed in 3.5.2 and 3.9.2 of the MASPS. The 4.8 dB difference is due to the factor R_C in [L.13]; that is, $10\log_{10}(R_C) = 10\log_{10}(3) = 4.8\ \text{dB}$.

3. Sample Link Budgets

This section presents sample link budgets that summarize the computations discussed in Section L.2. Three sets of link budgets are presented for the ground-to-air and air-to-ground cases. These budgets correspond to the median ($\kappa = \frac{4}{3}$), and worst-case ($\kappa = 1$) ray-tracing model and the Johnson-Gierhart (95th percentile) model.

The sample budgets are computed on the basis of aircraft-to-ground station ranges in excess of 160 nmi. Link budgets for shorter ranges can be developed using the same methodology. The assumed system parameters for link budget computation are summarized in Table L-3.

Table L-3: Parameters for Sample Link Budgets

Ground Station Transmitter Power	25 W = 44 dBm
Ground Station Cable Loss	2 dB
Ground Station Antenna Gain	6 dBi
Airborne Transmit Power	15 W = 41.8 dBm
Airborne Cable Loss	3 dB
Airborne Antenna Gain	-4 dBi
Ground Station Receiver Noise Figure	10 dB
Airborne Receiver Noise Figure	14 dB
External System Noise Figure	10 dB
Modulation	D8PSK
Channel Symbol Rate	10,500 symbols per second

3.1 Ground-to-Air Link Budgets

Table L-4, Table L-5, and Table L-6 contain the ground-to-air (uplink) link budgets for distances of 160, 180, and 200 nmi. The aircraft altitude is held at 33,000 feet. Budgets are presented for ground station antenna heights of 33 and 50 feet. The median link budget (Table L-4) shows a positive residual system margin in all cases, but the worst-case (Table L-5) and 95th percentile (Table L-6) budgets have negative margins at the extreme range of 200 nmi. For the ray-tracing propagation model, the negative margin corresponds to a line of sight that is only negligibly above horizontal. This causes the path difference $r_1 + r_2 - \rho$ to be very nearly zero. The corresponding excess path loss, as given by [L.4], is also nearly zero. The Johnson-Gierhart model (Table L-6) predicts significantly less loss in this extreme case.

The negative margin of –0.9 dB within the Johnson-Gierhart link budget can be easily overcome by increasing the transmitter power to 50 W (47 dBm), as required by the FAA NEXCOM specification.

Note: The uplink calculations in Tables L-4, L-5, and L-6 are based on the (uncorrected) BER of 10^{-3} for both Mode 2 and Mode 3. The ICAO

SARPs require a corrected BER of 10^{-4} for Mode 2 data operations. When the effects of the Reed-Solomon encoding/decoding are included to transform the uncorrected BER to the corrected BER, the link margins for Mode 2 operations are reduced by 0.8 dB from those shown in Tables L-4, L-5, and L-6. When viewed from a packet-error-rate standpoint under the assumption that a packet contains 248 octets of data, the difference in performance may approach 2 dB, with VDL Mode 3 offering the same performance at lower received power levels. The common standard performance of 10^{-3} (uncorrected) BER has been established to simplify the design and qualification of ground and airborne hardware supporting both VDL Modes. System implementers are cautioned to account for the different performance when establishing coverage areas and operational procedures.

Table L-4: Sample Ground-to-Air Long-Range Link Budgets Using Ray-Tracing and Effective Earth Radius Factor $\kappa = \frac{4}{3}$ (Median)

	Link Budget Parameter	Ground-to-Air $h_2 = 33{,}000$ ft					
1	Air-to-Ground Slant Range (nmi) ρ	160	180	200	160	180	200
2	Ground Antenna Height (ft) h_1	33.0	33.0	33.0	50.0	50.0	50.0
3	Transmitter Power (dBm) P_T	44.0	44.0	44.0	44.0	44.0	44.0
4	Transmit antenna gain (dBi) G_T	6.0	6.0	6.0	6.0	6.0	6.0
5	Transmit Line losses (dB) L_T	2.0	2.0	2.0	2.0	2.0	2.0
6	Transmit EIRP (dBm) $P_T \times (G_T / L_T)$	48.0	48.0	48.0	48.0	48.0	48.0
7	Free space Loss (dB) L_{FS}	124.6	125.6	126.6	124.6	125.6	126.6
8	Excess Path Loss (dB) L_{GR}	0.7	4.4	10.0	-2.4	0.9	6.4
9	Receive antenna gain (dBi) G_R	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
10	Receiver Line Loss (dB) L_R	3.0	3.0	3.0	3.0	3.0	3.0
11	Received Signal Level (dBm) P_R	-84.4	-89.1	-95.6	-81.2	-85.6	-92.0
12	Receiver Noise Figure (dB) F_{RECV}	14.0	14.0	14.0	14.0	14.0	14.0
13	Receiver Noise Power Density (dBm/Hz)	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0
14	External Noise Figure (dB) F_{EXT}	10.0	10.0	10.0	10.0	10.0	10.0
15	External Noise Power Density (dBm/Hz)	-164.0	-164.0	-164.0	-164.0	-164.0	-164.0
16	Receiver Cable Losses (dB) L_R	3.0	3.0	3.0	3.0	3.0	3.0
17	System Noise Temp at Antenna Output (dBK)	42.3	42.3	42.3	42.3	42.3	42.3
18	System Noise Temp at Receiver Input (dBK)	39.3	39.3	39.3	39.3	39.3	39.3
19	Total system noise power density (dBm/Hz)	-159.1	-159.1	-159.1	-159.1	-159.1	-159.1
20	Total system noise power in 10.5 kHz(dBm)	-118.9	-118.9	-118.9	-118.9	-118.9	-118.9
21	Theory Es/No for Spec Block Error Rate	17.8	17.8	17.8	17.8	17.8	17.8
22	Raised Cosine Filter Loss (dB)	1.8	1.8	1.8	1.8	1.8	1.8
23	Transmitter Implementation Loss (dB)	1.0	1.0	1.0	1.0	1.0	1.0
24	Receiver Implementation Loss (dB)	1.2	1.2	1.2	1.2	1.2	1.2
25	Required Es/No (dB)	21.8	21.8	21.8	21.8	21.8	21.8
26	Required Receiver Sensitivity (dBm)	-98.0	-98.0	-98.0	-98.0	-98.0	-98.0
27	Es/No Available (dB)	34.5	29.9	23.3	37.7	33.3	26.9
28	Residual System Margin (dB)	12.8	8.1	1.5	15.9	11.5	5.1

Table L-5: Sample Ground-to-Air Long-Range Link Budgets Using Ray-Tracing and Effective Earth Radius Factor $\kappa = 1$ (Worst Case)

	Link Budget Parameter	Ground-to-Air, $h_2 = 33,000$ ft					
1	Air-to-Ground Slant Range (nmi) ρ	160	180	200	160	180	200
2	Ground Antenna Height (ft) h_1	33.0	33.0	33.0	50.0	50.0	50.0
3	Transmitter Power (dBm) P_T	44.0	44.0	44.0	44.0	44.0	44.0
4	Transmit antenna gain (dBi) G_T	6.0	6.0	6.0	6.0	6.0	6.0
5	Transmit Line losses (dB) L_T	2.0	2.0	2.0	2.0	2.0	2.0
6	Transmit EIRP (dBm) $P_T \times (G_T / L_T)$	48.0	48.0	48.0	48.0	48.0	48.0
7	Free space Loss (dB) L_{FS}	124.6	125.6	126.6	124.6	125.6	126.6
8	Excess Path Loss (dB) L_{GR}	4.2	12.3	134.3	0.8	8.6	132.6
9	Receive antenna gain (dBi) G_R	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
10	Receiver Line Loss (dB) L_R	3.0	3.0	3.0	3.0	3.0	3.0
11	Received Signal Level (dBm) P_R	-87.9	-96.9	-219.9	-84.4	-93.2	-218.2
12	Receiver Noise Figure (dB) F_{RECV}	14.0	14.0	14.0	14.0	14.0	14.0
13	Receiver Noise Power Density (dBm/Hz)	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0
14	External Noise Figure (dB) F_{EXT}	10.0	10.0	10.0	10.0	10.0	10.0
15	External Noise Power Density (dBm/Hz)	-164.0	-164.0	-164.0	-164.0	-164.0	-164.0
16	Receiver Cable Losses (dB) L_R	3.0	3.0	3.0	3.0	3.0	3.0
17	System Noise Temp at Antenna Output (dBK)	42.3	42.3	42.3	42.3	42.3	42.3
18	System Noise Temp at Receiver Input (dBK)	39.3	39.3	39.3	39.3	39.3	39.3
19	Total system noise power density (dBm/Hz)	-159.1	-159.1	-159.1	-159.1	-159.1	-159.1
20	Total system noise power in 10.5 kHz(dBm)	-118.9	-118.9	-118.9	-118.9	-118.9	-118.9
21	Theory Es/No for Spec Block Error Rate	17.8	17.8	17.8	17.8	17.8	17.8
22	Raised Cosine Filter Loss (dB)	1.8	1.8	1.8	1.8	1.8	1.8
23	Transmitter Implementation Loss (dB)	1.0	1.0	1.0	1.0	1.0	1.0
24	Receiver Implementation Loss (dB)	1.2	1.2	1.2	1.2	1.2	1.2
25	Required Es/No (dB)	21.8	21.8	21.8	21.8	21.8	21.8
26	Required Receiver Sensitivity (dBm)	-98.0	-98.0	-98.0	-98.0	-98.0	-98.0
27	Es/No Available (dB)	31.0	22.0	-101.0	34.5	25.7	-99.3
28	Residual System Margin (dB)	9.2	0.2	-122.8	12.7	3.9	-121.1

Table L-6: Sample Ground-to-Air Long-Range Link Budgets Using Johnson-Gierhart Propagation Model (95th Percentile)

	Link Budget Parameter	Ground-to-Air, $h_2 = 33{,}000$ ft	
1	Air-to-Ground Slant Range (nmi) ρ	160	200
2	Ground Antenna Height (ft) h_1	50.0	50.0
3	Transmitter Power (dBm) P_T	44.0	44.0
4	Transmit antenna gain (dBi) G_T	6.0	6.0
5	Transmit Line losses (dB) L_T	2.0	2.0
6	Transmit EIRP (dBm) $P_T \times (G_T / L_T)$	48.0	48.0
7	Free space Loss (dB) L_{FS}	124.6	126.6
8	Excess Path Loss (dB) L_{GR}	4.0	11.9
9	Receive antenna gain (dBi) G_R	-4.0	-4.0
10	Receiver Line Loss (dB) L_R	3.0	3.0
11	Received Signal Level (dBm) P_R	-87.6	-97.5
12	Receiver Noise Figure (dB) F_{RECV}	14.0	14.0
13	Receiver Noise Power Density (dBm/Hz)	-160.0	-160.0
14	External Noise Figure (dB) F_{EXT}	10.0	10.0
15	External Noise Power Density (dBm/Hz)	-164.0	-164.0
16	Receiver Cable Losses (dB) L_R	3.0	3.0
17	System Noise Temp at Antenna Output (dBK)	42.3	42.3
18	System Noise Temp at Receiver Input (dBK)	39.3	39.3
19	Total system noise power density (dBm/Hz)	-159.1	-159.1
20	Total system noise power in 10.5 kHz(dBm)	-118.9	-118.9
21	Theory Es/No for Spec Block Error Rate	17.8	17.8
22	Raised Cosine Filter Loss (dB)	1.8	1.8
23	Transmitter Implementation Loss (dB)	1.0	1.0
24	Receiver Implementation Loss (dB)	1.2	1.2
25	Required Es/No (dB)	21.8	21.8
26	Required Receiver Sensitivity (dBm)	-98.0	-98.0
27	Es/No Available (dB)	30.7	20.9
28	Residual System Margin (dB)	8.9	-0.9

3.2 Air-to-Ground Link Budgets

Table L-7, Table L-8, and Table L-9 contain the air-to-ground (downlink) link budgets for distances of 160, 180, and 200 nmi. The aircraft altitude is held at 33,000 feet. Budgets are presented for ground station antenna heights of 33 and 50 feet. The median link budget (Table L-7) shows a positive residual system margin in all cases, but the worst-case (Table L-8) and 95th percentile (Table L-9) budgets have negative margins at the extreme range of 200 nmi, and the worst-case budget (Table L-9) also exhibits a negative margin at 180 nmi. For the ray-tracing propagation model, the negative margin corresponds to a line of sight that is only negligibly above horizontal. This causes the path difference $r_1 + r_2 - \rho$ to be very nearly zero. The corresponding excess path loss, as given by [L.4], is also nearly zero. The Johnson-Gierhart model (Table L-6) predicts significantly less loss in this extreme case.

The negative margin of –1.3 dB within the Johnson-Gierhart link budget could be overcome by increasing the transmitter power to 20 W (43 dBm), but this would not be a *minimum* requirement.

Note: The downlink calculations in Tables L-7, L-8, and L-9 are based on the (uncorrected) BER of 10^{-3} for both Mode 2 and Mode 3. The ICAO SARPs require a corrected BER of 10^{-4} for Mode 2 data operations. When the effects of the Reed-Solomon encoding/decoding are included to transform the uncorrected BER to the corrected BER, the link margins for Mode 2 operations are reduced by 0.8 dB from those shown in Tables L-7, L-8, and L-9. When viewed from a packet-error-rate standpoint under the assumption that a packet contains 248 octets of data, the difference in performance may approach 2 dB, with VDL Mode 3 offering the same performance at lower received power levels. The common standard performance of 10^{-3} (uncorrected) BER has been established to simplify the design and qualification of ground and airborne hardware supporting both VDL Modes. System implementers are cautioned to account for the different performance when establishing coverage areas and operational procedures.

Table L-7: Sample Air-to-Ground Long-Range Link Budgets Using Ray-Tracing and Effective Earth Radius Factor $\kappa = \frac{4}{3}$ (Median)

	Link Budget Parameter	Air-to-Ground, $h_2 = 33{,}000$ ft					
1	Air-to-Ground Slant Range (nmi) ρ	160	180	200	160	180	200
2	Ground Antenna Height (ft) h_1	33.0	33.0	33.0	50.0	50.0	50.0
3	Transmitter Power (dBm) P_T	41.8	41.8	41.8	41.8	41.8	41.8
4	Transmit antenna gain (dBi) G_T	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
5	Transmit Line losses (dB) L_T	3.0	3.0	3.0	3.0	3.0	3.0
6	Transmit EIRP (dBm) $P_T \times (G_T / L_T)$	34.8	34.8	34.8	34.8	34.8	34.8
7	Free space Loss (dB) L_{FS}	124.6	125.6	126.6	124.6	125.6	126.6
8	Excess Path Loss (dB) L_{GR}	0.7	4.4	10.0	-2.4	0.9	6.4
9	Receive antenna gain (dBi) G_R	6.0	6.0	6.0	6.0	6.0	6.0
10	Receiver Line Loss (dB) L_R	2.0	2.0	2.0	2.0	2.0	2.0
11	Received Signal Level (dBm) P_R	-86.6	-91.3	-97.8	-83.4	-87.8	-94.2
12	Receiver Noise Figure (dB) F_{RECV}	10.0	10.0	10.0	10.0	10.0	10.0
13	Receiver Noise Power Density (dBm/Hz)	-164.0	-164.0	-164.0	-164.0	-164.0	-164.0
14	External Noise Figure (dB) F_{EXT}	13.0	13.0	13.0	13.0	13.0	13.0
15	External Noise Power Density (dBm/Hz)	-161.0	-161.0	-161.0	-161.0	-161.0	-161.0
16	Receiver Cable Losses (dB) L_R	2.0	2.0	2.0	2.0	2.0	2.0
17	System Noise Temp at Antenna Output (dBK)	40.0	40.0	40.0	40.0	40.0	40.0
18	System Noise Temp at Receiver Input (dBK)	38.0	38.0	38.0	38.0	38.0	38.0
19	Total system noise power density (dBm/Hz)	-160.4	-160.4	-160.4	-160.4	-160.4	-160.4
20	Total system noise power in 10.5 kHz(dBm)	-120.2	-120.2	-120.2	-120.2	-120.2	-120.2
21	Theory Es/No for Spec Block Error Rate	17.8	17.8	17.8	17.8	17.8	17.8
22	Raised Cosine Filter Loss (dB)	1.8	1.8	1.8	1.8	1.8	1.8
23	Transmitter Implementation Loss (dB)	1.0	1.0	1.0	1.0	1.0	1.0
24	Receiver Implementation Loss (dB)	1.2	1.2	1.2	1.2	1.2	1.2
25	Required Es/No (dB)	21.8	21.8	21.8	21.8	21.8	21.8
26	Required Receiver Sensitivity (dBm)	-102.0	-102.0	-102.0	-102.0	-102.0	-102.0
27	Es/No Available (dB)	33.6	28.9	22.3	36.8	32.4	26.0
28	Residual System Margin (dB)	11.8	7.1	0.5	15.0	10.6	4.2

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Table L-8: Sample Air-to-Ground Long-Range Link Budgets Using Ray-Tracing and Effective Earth Radius Factor $\kappa = 1$ (Worst Case)

	Link Budget Parameter	Air-to-Ground, $h_2 = 33,000$ ft					
1	Air-to-Ground Slant Range (nmi) ρ	160	180	200	160	180	200
2	Ground Antenna Height (ft) h_1	33.0	33.0	33.0	50.0	50.0	50.0
3	Transmitter Power (dBm) P_T	41.8	41.8	41.8	41.8	41.8	41.8
4	Transmit antenna gain (dBi) G_T	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
5	Transmit Line losses (dB) L_T	3.0	3.0	3.0	3.0	3.0	3.0
6	Transmit EIRP (dBm) $P_T \times (G_T / L_T)$	34.8	34.8	34.8	34.8	34.8	34.8
7	Free space Loss (dB) L_{FS}	124.6	125.6	126.6	124.6	125.6	126.6
8	Excess Path Loss (dB) L_{GR}	4.2	12.3	134.3	0.8	8.6	132.6
9	Receive antenna gain (dBi) G_R	6.0	6.0	6.0	6.0	6.0	6.0
10	Receiver Line Loss (dB) L_R	2.0	2.0	2.0	2.0	2.0	2.0
11	Received Signal Level (dBm) P_R	-90.1	-99.2	-222.1	-86.6	-95.4	-220.4
12	Receiver Noise Figure (dB) F_{RECV}	10.0	10.0	10.0	10.0	10.0	10.0
13	Receiver Noise Power Density (dBm/Hz)	-164.0	-164.0	-164.0	-164.0	-164.0	-164.0
14	External Noise Figure (dB) F_{EXT}	13.0	13.0	13.0	13.0	13.0	13.0
15	External Noise Power Density (dBm/Hz)	-161.0	-161.0	-161.0	-161.0	-161.0	-161.0
16	Receiver Cable Losses (dB) L_R	2.0	2.0	2.0	2.0	2.0	2.0
17	System Noise Temp at Antenna Output (dBK)	40.0	40.0	40.0	40.0	40.0	40.0
18	System Noise Temp at Receiver Input (dBK)	38.0	38.0	38.0	38.0	38.0	38.0
19	Total system noise power density (dBm/Hz)	-160.4	-160.4	-160.4	-160.4	-160.4	-160.4
20	Total system noise power in 10.5 kHz(dBm)	-120.2	-120.2	-120.2	-120.2	-120.2	-120.2
21	Theory Es/No for Spec Block Error Rate	17.8	17.8	17.8	17.8	17.8	17.8
22	Raised Cosine Filter Loss (dB)	1.8	1.8	1.8	1.8	1.8	1.8
23	Transmitter Implementation Loss (dB)	1.0	1.0	1.0	1.0	1.0	1.0
24	Receiver Implementation Loss (dB)	1.2	1.2	1.2	1.2	1.2	1.2
25	Required Es/No (dB)	21.8	21.8	21.8	21.8	21.8	21.8
26	Required Receiver Sensitivity (dBm)	-102.0	-102.0	-102.0	-102.0	-102.0	-102.0
27	Es/No Available (dB)	30.1	21.0	-102.0	33.5	24.8	-100.2
28	Residual System Margin (dB)	8.3	-0.8	-123.8	11.7	3.0	-122.0

Table L-9: Sample Air-to-Ground Long-Range Link Budgets Using Johnson-Gierhart Propagation Model (95th Percentile)

	Link Budget Parameter	**Air-to-Ground,** $h_2 = 33{,}000$ ft	
1	Air-to-Ground Slant Range (nmi) ρ	160	200
2	Ground Antenna Height (ft) h_1	50.0	50.0
3	Transmitter Power (dBm) P_T	41.8	41.8
4	Transmit antenna gain (dBi) G_T	-4.0	-4.0
5	Transmit Line losses (dB) L_T	3.0	3.0
6	Transmit EIRP (dBm) $P_T \times (G_T / L_T)$	34.8	34.8
7	Free space Loss (dB) L_{FS}	124.6	126.6
8	Excess Path Loss (dB) L_{GR}	4.0	11.9
9	Receive antenna gain (dBi) G_R	6.0	6.0
10	Receiver Line Loss (dB) L_R	2.0	2.0
11	Received Signal Level (dBm) P_R	-89.8	-99.7
12	Receiver Noise Figure (dB) F_{RECV}	10.0	10.0
13	Receiver Noise Power Density (dBm/Hz)	-164.0	-164.0
14	External Noise Figure (dB) F_{EXT}	13.0	13.0
15	External Noise Power Density (dBm/Hz)	-161.0	-161.0
16	Receiver Cable Losses (dB) L_R	2.0	2.0
17	System Noise Temp at Antenna Output (dBK)	40.0	40.0
18	System Noise Temp at Receiver Input (dBK)	38.0	38.0
19	Total system noise power density (dBm/Hz)	-160.4	-160.4
20	Total system noise power in 10.5 kHz(dBm)	-120.2	-120.2
21	Theory Es/No for Spec Block Error Rate	17.8	17.8
22	Raised Cosine Filter Loss (dB)	1.8	1.8
23	Transmitter Implementation Loss (dB)	1.0	1.0
24	Receiver Implementation Loss (dB)	1.2	1.2
25	Required Es/No (dB)	21.8	21.8
26	Required Receiver Sensitivity (dBm)	-102.0	-102.0
27	Es/No Available (dB)	30.3	20.5
28	Residual System Margin (dB)	8.5	-1.3

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Appendix M

VHF Channel Labels

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M.1 VHF Channel Labels

The VDL Mode 3 system has a channel labelling plan that allows users to select and access the voice channel of a designated airspace. This plan was developed so that each possible VHF voice channel in the existing global ATC VHF voice communications system has a unique label. The plan serves 25 kHz and 8.33 kHz analog DSB-AM voice channels and 25 kHz digital TDMA voice/data channels for VDL Mode 3. The labelling plan also accommodates 25 kHz VDL Mode 2 digital CSMA data channels in VHF band separate from the ATC bands. The frequency usage in a particular airspace is dependent upon the preset ground system capability.

In Table M-1, each VHF Channel designator has six digits, but most significant digit “one” is common to all, so only the last five digits are required to define a specific channel. For 25 kHz analog channels, the last digits are 00, 25, or 75. For 25 kHz VDL Mode 3 channels, the slot identifiers A through D are represented by the last digit of the channel label ending in 1, 2, 3, or 4. For 8.33 kHz analog channels, the last digit ends in 5 or 0, but because the label is not evenly divisible by 25, it does not duplicate any 25 kHz channel label. The highest valid channel label has been reserved exclusively on a worldwide basis for use as a VDL Mode 2.

Table M-1: VHF Channel Labels

Frequency (MHz)	*Time Slot*	*Channel Spacing (kHz)*	*Channel*
118.0000		25	118.000
118.0000	A	25	118.001
118.0000	B	25	118.002
118.0000	C	25	118.003
118.0000	D	25	118.004
118.0000		8.33	118.005
118.0083		8.33	118.010
118.0167		8.33	118.015
118.0250	A	25	118.021
118.0250	B	25	118.022
118.0250	C	25	118.023
118.0250	D	25	118.024
118.0250		25	118.025
118.0250		8.33	118.030
118.0333		8.33	118.035
118.0417		8.33	118.040
118.0500		25	118.050
118.0500	A	25	118.051
118.0500	B	25	118.052
118.0500	C	25	118.053
118.0500	D	25	118.054
118.0500		8.33	118.055
118.0583		8.33	118.060
118.0667		8.33	118.065
118.0750	A	25	118.071
118.0750	B	25	118.072
118.0750	C	25	118.073
118.0750	D	25	118.074
118.0750		25	118.075
118.0750		8.33	118.080
118.0833		8.33	118.085
118.0917		8.33	118.090
118.1000		25	118.100
etc.			
136.975		25	136.975

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